Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems

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Proceedings of the Symposium
December 11-13, 1978
Callaway Gardens, Georgia

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Foreword

A regional riparian symposium was held in Tucson, Arizona, July 9, 1977. The proceedings volume of that gathering, entitled "Importance, preservation and management of riparian habitat: a symposium," was published by the Rocky Mountain Forest and Range Experiment Station. Featured in that volume are 27 papers highlighting "what is known about this unique, diminishing vegetative type: characteristics, classification systems associated fauna, use conflicts, management alternatives, and research needs." After quickly exhausting two printings of those proceedings it was decided that demands for a national riparian symposium were justified.

The word riparian is derived from the latin rip(a), meaning bank [of a stream]. Scientists used the word early for in 1758 Linnaeus gave the Bank Swallow the specific name riparia, referring to the bank-nesting habit of this species. For centuries riparian law and water rights have been the subject of court battles and even open warfare. These rights, which traditionally belong to the owner of riparian property, pertain to fishing and other uses of a stream, including irrigation and the generation of electricity.

The combination of water and the associated lush habitat makes riparian areas the most notable example of multiple use lands. These areas are widely sought after for the raising of crops and livestock, building of homes and industrial sites and storage projects which provide water for irrigation, power, and municipal and industrial use. As currently practiced these programs are commonly detrimental to many wildlife, recreational, scenic and aesthetic values. Only recently have serious attempts been made to retain some of these latter values when developing technological projects. Technologists and scientists when addressing problems and values of aquatic riverine systems have often ignored the importance of closely allied riparian ecosystems.

Papers presented at this first national riparian symposium deal with several aspects of riparian ecology which have only recently become known. The complexity of these systems with their great biological diversity and intricate physicochemical processes render them difficult to study and, at the same time, important to understand. For example, we have only recently begun to determine the intricacies of the role of riparian ecosystems in the maintenance of clean, life-sustaining water. The importance of riparian vegetation in the production of oxygen and air purification has still not been fully determined. Included papers address the premium values of riparian areas for wildlife and recreational purposes as well as attempting to quantify these values.

Through long-term patterns we have acknowledged the outstanding multiple values of riparian systems. However, we have only recently begun to address the many associated problems. Conflicts in uses and values continue to be ignored as flooded settlements are rebuilt in floodplains and reservoirs are established in areas of high evaporation, excessive seepage, active fault zones and increasing salinity. Projects which attempt to protect lives as well as property in flood-prone riparian areas are discussed. Despite increasing costs to taxpayers some of these projects are ineffective or even counter productive. Alternatives to flood control projects include floodplain zoning and stricter legislation relating to flood insurance.

A decade ago ignorance led us to believe that popular and scientific riparian concerns were few. General concerns were related to flood control, maintaining agricultural and urban activities and management for game species. Not until this decade have we begun to seriously examine the many additional issues including recreational values, importance to maintaining clean water and air and preservation of healthy ecosystems. Ten years ago many resource managers responsible for riparian areas were not even familiar with the term. Today, although technically an adjective, the word riparian has been "elevated" to a noun by those who speak of "the riparian." Riparian research and management has finally come of age.

R. Roy Johnson

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Session Chairmen:

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Opening Address:

Ecological Importance of the Riparian Zone[1]

Eugene P. Odum[2]

Abstract.--Riparian zones have their greatest value as buffers and filters between man's urban and agricultural development and his most vital life-support resource - water. Preservation based on public riparian rights provide an effective hedge against overdevelopment of urban sprawl and agricultural or forest monoculture.

Riparian zones are well-defined landscape features that have many of the same values and land-use problems as wetlands in general, but are nevertheless distinct enough to warrant special consideration. For one thing, floodplains are ubiquitous, found wherever there is running or standing water. For another, riparian habitats are ecotonal in nature with elongate shapes and very high edge-to-area ratios. As functional ecosystems, they are very open with large energy, nutrient and biotic interchanges with aquatic systems on the inner margin and upland terrestrial ecosystems on the other margin. Accordingly, even though they may be physiographically distinct, most riparian zones cannot be dealt with as separate functional entities, as has been customary with the large and broad wetlands such as coastal marshes or the Okefenokee Swamp. Rather, riparian habitats are best evaluated and managed (where necessary) as parts of larger landscape units such as watersheds.

THE WATER FLOW FORCING FUNCTION

As is widely recognized, hydroperiod is the key external or forcing function that determines vegetative composition and productivity. What is perhaps not so well understood is that the intensity of flooding is as important as the frequency. Flooding can both enhance and stress a riparian ecosystem, depending on frequency, timing, and intensity. Over the annual cycle, benefits seem to exceed metabolic costs in natural floodplains where organisms are well adapted to the flooding regime.

Figure 1 is a graphic model, partly data-based partly hypothetical, of subsidy-stress responses to a gradient flooding.

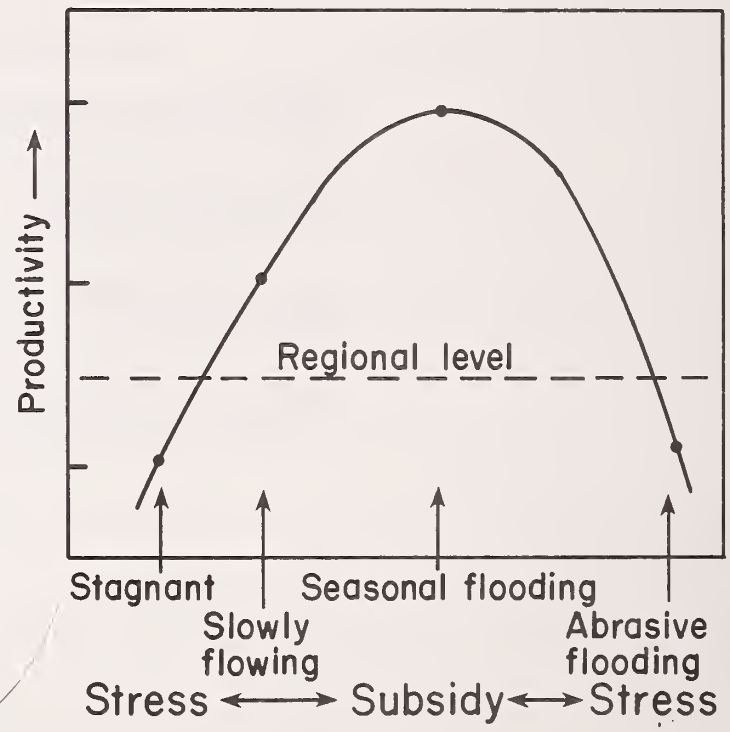

Figure 1. The effect of a gradient of flooding on productivity as compared with a regional level that might be expected in the absence of standing or flooding water. The graphic model takes the form on a stress-subsidy curve. For southern swamps Conner and Day (1976) have estimated annual net production for stagnant, slowly flowing and seasonal flooding conditions as of the order of 0.2, 0.7, and 1.2 kgm dry matter per square meter, respectively.

The extremes of stagnant water, on the one hand, or abrasive flooding on the other stress the biotic community and reduce productivity. In contrast, flowing water or the gentle kind of seasonal flooding so characteristic of natural floodplains in natural watersheds generally increase productivity, as compared with adjacent

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[1]Opening address, National Symposium on Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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uplands (regional level of Fig. 1). There are, of course, many modifying and mitigating factors, such as the season of flooding (whether during growing season or dormant season, for example) which will affect overall responses, or shift the performance curve of Figure 1 to the left or to the right. Many of these secondary factors are to be discussed in papers presented at this symposium.

Unfortunately, society's efforts to control floods that involve constructing upstream dams, channelization, or diking the streamside margins often result in reducing subsidies and increasing the stresses. Thus, riparian productivity is reduced when the normal seasonal flooding is abolished or reduced by dams (for documented example see Johnson, et al., 1976). Dikes may also do the same, and, in addition, they cause flood waters to rise higher within the constricted channel so that when water does overtop or break through the dike a very abrasive overwash torrent is produced that destroys both natural and man-made structures. Belt (1971) has documented such a situation in regard to recent Mississippi river floods. Accordingly, future management should focus on means of reducing man-made flood stress and restoring the natural water-flow subsidies. Nothing of great value, such as expensive homes or factories, should be constructed on floodplains unless they can be built on posts or otherwise elevated to escape normal flooding.

EDGE EFFECTS

When it comes to wildlife and animal populations in general, the riparian zone provides an almost classic example of the ecological principle of "edge effect". Both density and diversity of species tends to be higher at the land-water ecotone than in adjacent uplands, especially where regional climates are arid or are characterized by dry periods. Not only are there many small species that are restricted or endemic to the riparian habitat but many, if not most, large animals such as big game require access to stream or lake margins for survival even though they may spend much of their time elsewhere. The riparian strip also provides the natural highways by which animals can move safely from one place to another.

Since small difference in elevation creates marked differences in soil the variety of habitats within the floodplain itself is potentially very large. Ox-bow ponds and lakes in floodplains are incredibly rich in life because they are rejuvinated, restocked and refertilized by periodic flooding much in the same way that agricultural man manages his rice paddies or fish ponds; and the work of cultivation and fertilization is a free service of nature that does not require the use of expensive fossil fuel energy! Whenever I teach field or faunistic zoology, I always take my class to a floodplain pond because within a relatively short time one may collect examples of every phyla, and almost every class, in the animal kingdom. The largest freshwater black bass every caught in Georgia came out of an ox-bow lake on a large river floodplain. These are just two examples to illustrate the natural heritage to be found on floodplains.

RIPARIAN ZONES AS "HEDGES" AGAINST OVERDEVELOPMENT

We can make a strong case, I believe, for the proposition that riparian zones have their greatest value as buffers between man's urban and agricultural development and his most vital natural resource - water. Where floodplains and other riparian ecosystems are maintained in a natural or, at least, semi-natural state a very desirable landscape or "beta" diversity is achieved. In ecology, we often speak of the diversity of habitats in a large region as between-habitat or "beta" diversity in contrast to within-habitat or "alpha" diversity, as was discussed in the previous section of this commentary. Riparian green belts generously interdispersed among urban-industrial and agricultural areas stand as an effective "hedge" against both urban overdevelopment and too much agricultural and forest monoculture. Riparian greenbelts not only provide a welcome scenic relief from monotonous man-made landscapes but they also function as filters to reduce the deleterious impact of man's high energy consuming and polluting activities on water quality. It is particularly urgent just now that we be able to document more clearly the value of riparian zones as filters for runoff from croplands, since farmers are going to be under more and more pressure to get a few more bushels of corn or soybeans by farming right up to the banks of streams, even though this will require energy-expensive channelization and drainage at taxpayers expense. At the University of Georgia Agricultural Experiment Station on the Coastal Plain, ecologists have joined agronomists in a study that will compare downstream water conditions and long-term benefit-costs in agricultural watersheds with and without natural riparian vegetation. We think the former will come out the winner, but we must get the facts and figures to prove it!

In relatively flat country such as the great river valleys and coastal plains riparian ecosystems and other wetlands play the same role in creating a desirable beta diversity as do the peaks and ridges in mountainous country. In California, the mountains are barriers to

overdevelopment, but in a flat state such as Florida, the wetlands are just about the only natural feature that stands in the way of the spread of urban sprawl from one end of the state to the other, a situation certainly neither desirable for, nor desired by, Floridians. It is not surprising that preservation of wetlands is receiving a high priority in that state.

As described elsewhere (Odum and Kroodsma, 1977) the Department of Energy's Savannah River Plant Reservation provides a good example of a landscape where high beta diversity for the area as a whole compensates for low alpha diversity on the upland. All of the upland that had been farmed when the Plant was established in 1952 (about one-third of the area) has now been converted to pine plantations that are to be harvested and managed on a short rotation (clear, cut and replant) for maximum production of wood pulp. Thus, the within-habitat, or alpha diversity, of much of the upland is essentially zero (one species stands), but because the numerous stream floodplains and other low-lying wetlands have been left in their natural state, the reservation as a whole has a reasonably good diversity (Shannon index of 2.3, and evenness index of 0.7 on a scale of 0-1). Wildlife thrives and the riparian diversity has had much to do with ameliorating the impacts of thermal discharges and radioactive spills. Several years ago the Forest Service proposed increasing the coverage of pine which would mean replacing a lot of the hardwood stands and natural floodplain forests with pine monoculture. We calculated that to increase pine coverage from the present 36% of the area to 50 or 75% would drastically reduce the beta habitat diversity. I believe we have convinced the Forest Service that such a move would constitute expensive overdevelopment (too much of a good thing) and would greatly reduce the ability of the landscape to buffer and filter the byproducts of the high energy facilities on the site.

PUBLIC RIPARIAN RIGHTS

Since the market system, the chief "forcing function" in today's decision-making, generally favors development for private gain over preservation for public good, it is necessary to develop a much better system for evaluating and promoting public values. Most of all, this means establishing public opinion and legal precedence for preservation so that "riparian rights" will include public as well as private values. Hopefully, it will not be too long before floodplains will be treated the same as navigable streams, namely, as natural resources to be used and enjoyed but not to be destroyed, built on, or modified willy-nilly to the detriment of society as a whole.

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Keynote Address:

A Systems Approach to Management Strategies[1]

ROBERT L. HERBST[2]

I accepted with pleasure the assignment of making the keynote address at this conference for two basic reasons. First, because it gave me the opportunity to discuss with a learned group of men and women a subject of crucial importance in an area where I hold some awesome responsibilities; second, because it provided a forum for sharing with you the philosophical views behind what I hope you will regard as an exciting new approach to natural resource management including that vastly important special environment we call the "riparian systems."

The many roles of these delicate ecotones are so complex as to be scarcely yet understood. One vital role is support of wildlife populations, as in the rich Eastern bottomland hardwoods and the riparian systems of the West where they are the sole support of many wildlife. But today much of this important wildlife habitat has disappeared. Human pre-emption has thus left riparian systems as our major base, nationwide, for conserving the remnants of our untamed life forms.

In addition, the intrinsic values of riparian systems for recreation, aesthetics and a host of other purposes are coming strongly to the nation's attention. But basically, within the context of the total biosphere, their most important function is the linkage they perform as energy and matter transactors between whatever systems lie on either side.

On the dry side, these systems can range from forests to grasslands, from woodlands to deserts. The nutrients and energies from these biomes flow into the riparian systems and interface there with the wet side of the ecotone--streams, rivers, lakes, estuaries, wetlands or bays. As managers of the wildlife actors in the riparian dramas, we must be ever mindful of these flows and careful not to disrupt them as we go about our specific management duties. If we cut into the flow, no matter how inadvertently, the result could be starvation for a host of hungry juveniles in some faraway estuary, waiting to feed and grow and become major components of our aquatic food chain.

When the benign riparian links are broken, or when the linkage is used to distribute inadvertent inputs of poisonous or clogging matter throughout the downstream systems, real trouble can result. As managers of much of this crucial set of systems, we are striving to increase our knowledge of the strange and wonderful ways they work and how to help keep them in good working order.

When you don't know enough to be a "wise guy," the safest stance is humility. It is also the beginning of wisdom. I think I can tell you in all honesty today, that we have crossed the threshold of humility and begun the task of attempting to find out what we don't know - which is a lot.

The bottom line for management is to know what you are managing, and the resource managing agencies that I administer are actively engaged in filling in the unknowns--the blanks in that bottom line. Until we understand how the systems work, we had better use every management tool at our disposal to protect them, and that is the job the Fish and Wildlife and National Park Services are working at today. The exciting new ways we are beginning to attack this task in Alaska provides a classic case study, to which I will return in a moment.

The job is not an easy one, and we find agencies at all levels of government working at cross purposes. Home owners who built on flood plains became indignant when those areas lived up to their name. As a result, the Flood Plain Insurance Act came into being, spelling aid to the home owners and death to the riparian systems.

Next came the builders of beach cottages--the developers of offshore islands and

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[1] Keynote address at the National Symposium on Strategies for Protection and Management of Riparian Ecosystems, Pine Mountain, Georgia, December 11, 1978.

[2] Robert L. Herbst, Assistant Secretary for Fish and Wildlife and Parks, U.S. Department of the Interior, Washington, D.C. 20240

estuaries. The lure of water was irresistible and the consequences of irresponsible development were only a hazy conditional clause that might never materialize. When the future arrived, in the manner that the systems decreed it would, half-informed people went to Congress, demanded laws, and, unfortunately, got them.

Flood plains, barrier islands, outer banks, primary dunes--the list of targets for poorly-conceived and ill-advised legislation is depressingly long. Bridges were funded to connect mainlands to islands destined to change their shapes and positions. Estuaries were honeycombed with marinas that altered the systems functions. Over 22 million acres of Mississippi River alluvial plain forested wetlands, targets of federally financed drainage, flood control projects and private development, have been destroyed in the past 50 years. Only three million acres remain and they are being destroyed at a rate of 300,000 acres annually.

Through it all runs the steady drumbeat of industry--permitted by local jurisdictions in the form of zoning allowances and underwritten in many cases by Federal reclamation grants. Dredging permits facilitate the barging of injurious materials along otherwise barely navigable streams. Swampy areas "good for nothing else" are turned into industrial parks, and when the heavy rains come, the stored materials associated with these industries far too often are found poisoning whole riverine and estuarine systems. Meanwhile, the perpetrators of these industrial mistakes shrug and look suggestively heavenward, signifying "an act of God."

I watched it happen in Minnesota, where soy bean oil stored in tanks along the river spilled out and was carried down the systems pathways until it had killed thousands of waterfowl all the way out onto the Mississippi River flood plains.

One small "plus" in today's restricted energy and economic outlook is the fact that government at all levels is hunting for just this kind of nonsensical expenditure to cancel out and help them balance their budgets.

Desertification is occurring at an alarming rate throughout the world; some sources estimate its rate at 60,000 square kilometers a year. This is equal to the loss of an area the size of Massachusetts, Vermont, Rhode Island and Connecticut annually. Irrigated land is degrading at 125,000 hectares per year and this further pressures the little remaining riparian habitat.

The fate of such habitat in the U.S. is tied to increasing needs for water by an expanding population. In 1970, daily water use was approximately 3,170 billion gallons or approximately eight times the average daily flow of the Mississippi River. In other words, each day 370 billion gallons, or about 1800 gallons per person, were diverted from streams and surface reservoirs or pumped from underground for domestic, industrial, rural or irrigational activities.

Projected needs by the year 2000 are for double this amount, but no one yet has told us where this can come from. The diversion of such large quantities of water has a profound effect not only on the rivers themselves, but on the associated riparian vegetation and the animal life that depends on that vegetation.

Symposia such as you engage in here are among the most fruitful actions we can take toward recognizing our inconsistencies and inadequacies, correcting our directions, and reshaping our management processes. This is what I am here to talk about, and I hope my remarks will generate the kind of feedback that will strengthen both jobs--the one you do and the one I do.

I would like to start by calling your attention to the systems orientation of this Administration. The major programs we have undertaken, from energy to inflation, have been entered into with a lively sense of the entire set of factors at work, at least insofar as they could be discerned. When we have had to settle for piecemeal, it has been on a "that-or-nothing" basis, and generally the reason has been that too little information was widely enough known to support a more informed set of actions. The dissemination of knowledge is a necessary step before support for acquiring new knowledge can be developed. Such dissemination increases the body of appreciation and understanding for what went before and what must follow, and this is something for all of us to remember.

In its last session, Congress passed probably the most significant piece of conservation legislation ever enacted at one stroke in the history of this nation. The comprehensive National Parks and Recreation Act of 1978 accomplishes a host of tasks that had been waiting for years to be addressed. It was a catch-up bill in the sense that it will now bring many programs to the point where they should have been--to where they MUST be if the larger whole is to be defined and managed sensibly.

Wild and scenic rivers, national scenic and historic trails, wilderness areas--those are just some of the components of what a few sought to disparage as "omnibus" legislation. Yet the lumping of so many objectives into one landmark package was more than a haphazard free ride on an omnibus. It was the beginning of recognition that certain things relate significantly to certain other things, and that these things can be handled intelligently only when their relationships are recognized in the way they are handled.

In short, we are slowly but surely approaching a set of conditions within which it will be possible to make our system of management fit the systems to be managed.

A systems approach to management allows for complementarity and diminishes polarity. Cutting, grazing, channelization and damming are usually instigated for what is perceived to be excellent reasons--at least by the instigators. Those who seek to preserve intact areas that can continue to support unique plant and animal species and the high recreational and aesthetic values they contribute--these people also see their goals as worthy.

However, no single interest can claim complete title to an entire system such as riparian ecosystems we consider here. My message, then, is twofold:

First, we must foster wider recognition of the far-reaching complexities--the long, looping chains of actions, reactions, feedbacks, and eventual backlashes that a system can generate. This objective must be sought at the scientific level through interaction among the specialized disciplines, and at the general populace level by means of environmental education of all kinds.

Second, we must seek the wider stage for management action and a wider cast of characters in the management drama, involving as much knowledge, as many of the interacting system components, and as widely representative a collection of special interest groups as can be coaxed into participation in the management process.

These two goals--a broader base of knowledge and a broader group of knowledgeable and interested participants--are the goals of this Administration, best expressed by the President and the Secretary of the Interior as "development within the context of environmental integrity."

What resource managers are just beginning to appreciate is the added impetus to true systems management that comes from today's energy constraints. Where we can preserve and even enhance the energetic natural systems, we can often learn to save ourselves today's fossil fuel bill and tomorrow's backlash from an abused or exhausted natural resource.

Not just dollars, beauty, and ethics, but energy is an item that counts heavily on behalf of whole systems management.

The relationship of money to energy is one of the more complex issues we have to deal with, but this much we know: Energy flows endlessly through the myriad complex systems of the biosphere, unaffected by human influence, and in every part of this great circular system, vast energies are released.

Only when these energies are harnessed to do work for society is money exchanged. And we never pay Nature--we only pay for the construction and repairs and all the human transactions that go into the harnessing of the systems.

In the National Park Service's monumental South Florida Carrying Capacity Study, we began to see for the first time how many hidden costs are carried under the cloak of development. Every time we develop, we add structure. Sometimes the structure is deliberately designed to change the course of nature's energy flows. Dams and channels are examples of this and we tend to count as pure gain the energies these structures make available to society.

But in the course of these changes, we cancel out a certain amount of the work nature was doing before we altered her course, and often that work--unrecognized or undervalued--becomes more apparent when it is NOT being done.

As a result, whole species whose makeup and work for the ecosystem is not understood are slipping forever from Earth. The jobs they were doing are vacant and no "Help Wanted" column advertises the empty positions. The jobs they might have done, had they been allowed to continue evolving toward some future date with destiny, will never be done. The natural economy simply adjusts downward a notch, to a slightly poorer status.

And that's not the end of it. The laws of energy are as unbreakable as the law of gravity. The law of Entropy--the Second Law of Thermodynamics--hits our

"developments" in two of our sorest spots. One is called maintenance and the other is called pollution.

When we build, we commit ourselves to maintainance, and eventually to replacement. Nature solved this problem a billion years ago with photosynthesis and respiration. Nature's systems run on the sun. Their structure is built, maintained and replaced by solar power.

When we build, we use irreplaceable fossil fuels and expensive nuclear power and we have to continue applying these purchased energies if we want to avoid the deterioration and demise that the Law of Entropy demands. Furthermore, as we build and as we maintain, our work throws off a certain amount of heat and other useless energies that we label "wastes" and that we expect Nature to pick up and dispose of.

No wonder we call nature "mother." Didn't mother always pick up after us? If yours was anything like mine, she did at first. But after awhile she began to let you know she was getting tired of doing it and that you'd better start keeping your things in order--cleaning up your own messes.

Something like that appears to be happening with our planetary housekeeping. Mother is tired of the mess and she's signaling strongly that she can't continue to do the job she has done in the past. It's high time we learned how she kept house and rearranged our accounting systems to reflect more accurately the true nature of all that we call "development."

If the work of science is to prosper, it must have public support. In order to reach the average citizen with the urgency of basic research, I ask them to picture a family in a lovely, well-run home. Enter a baby. He grows within the care and love of his family and eventually he begins to explore and manipulate his surroundings. He finds things to use as toys--builds towers out of blocks--makes a "cave" out of a table and a blanket. His mother smiles at his inventiveness and encourages it, patiently "putting things back."

Then comes a second baby, a third, a forth. Suddenly the inventiveness of the first charming child is being acted out in such strenuous volume that the mother's strength and ability to restore order is exhausted. The children by then may have worn out, broken, or lost most of the lovely things of which the house consisted.

Does this mean it's too late to do anything? Not if the children are bright enough to notice, concerned enough to care, and moral enough to get their act together and change their spoiled, selfish ways. If they are capable of understanding the makeup of the house and what has happened, they are also capable of judging their own past actions and forming some kind of team spirit and work effort--one that will begin to fit their actions into a systematized mode for dealing with the shambles they have made of their environment.

Something like this is the problem I face in my job--overseeing the work of two great land and water-based systems and the flora and fauna they support, the National Parks and Wildlife refuges and the activities of the HCRS, a Service concerned with our heritage from the past as well as our present and future recreation needs.

The world house is still in disorder, but we're beginning to discern its makeup. We're starting to take readings on its basic design, to reconstruct its past in our mind's eye, to protect it where it can still muster the energy to repair itself, and where it is still in a healthy, functioning condition, to give it the ultimate in helping hands--which is often "hands off."

For this kind of wise management we need systems understanding and a systems approach.

The late E.F. Schumacher, whose Small is Beautiful philosophy has become a planetary household word, wrote a book shortly before he died entitled A Guide for the Perplexed. In it he devoted a chapter to the nature of problems and the need for a flexible approach to those of a divergent nature. But he had something to say too about paying attention to questions that nature settled long ago and that no longer are a matter of choice--the laws of the universe that we must recognize whenever we build.

"Take a design problem," wrote Schumacher. "--say, how to make a two-wheeled, man-powered means of transportation. Various solutions are offered which gradually and increasingly converge, until finally a design emerges which is "the answer--a bicycle--an answer that turns out to be amazingly stable over time. Why is this answer so stable," Schumacher asks. And then he answers himself, and we should all listen.

"Simply because it complies with the laws of the universe--laws at the level of inanimate nature."

I bring this up here because it is these laws of nature, from the inanimate "physics" level on up through the subsequent systems—chemistry and biology--that we must deal with as we attempt to build a management system that fits the systems to be managed...tools to fit the job to be done.

We start with Gravity and the Conservation and Entropy laws of Thermodynamics and we build from there, paying careful attention at every level that what we build is firmly grounded on all the principles of the level below.

The level at which we build our tools is the sociological systems level. It is on this high and heady plane that we do our plotting, develop our strategy, keep our books. All of this work must be done in careful conformance with all the laws of nature that went into the building of society--the underpinnings of human life that we forget only at our peril--the laws of physics and chemistry and biology.

Ethics are a short cut for arriving at a respect for these absolutes. Where the laws are immediate and demanding, as in the Law of Gravity, no long and arduous way is needed to understanding. You don't require a Ph.D. in gravity to keep from falling down. Nor do you need the short cut, the ethical constraint, to remind you not to walk off a cliff. Everyone soon learns, usually at the cost of only a few bruises or a broken bone or two, that he cannot break the Law of Gravity. He can only transgress it, and in the process, break himself.

The law that demands maintenance and exacts the so-called "pollution" tax--the Law of Entropy--is just as ironclad as gravity, but it takes longer to work, and in the meantime the people who brought it into play may well have gotten out of the way.

The entropy tax accumulates slowly but relentlessly. As each person contributes his small share to the mounting burden, he shrugs and says "What can one person do?" But eventually society as a whole must pick up the cost, because we live within the system and we can't escape its laws.

I do not propose that we assume the burden of trying to educate the total population to an intellectual awareness of entropy. The heat tax from that much work would turn this cool, moist Earth into a burning star. But we CAN begin to impart a sense of systems, an awareness of each person's input into the total planetary pollution tax. We can "take the short cut" and try to instill a sense of responsibility, develop the climate for an environmental ethic that will, in effect, do the same job for our world that understanding at the graduate level would achieve.

When that millenium has been arrived at we can all congratulate ourselves and troop off to pick up our sainthood awards. Meanwhile, those of us who "would be building," as the hymn goes, have a systems management job to do. It starts with scientists such as you, and then it must quickly trickle down through all the action levels of society.

I call it "environmental education," but whatever it is, the wisdom that you people alone are capable of thoroughly understanding must very soon become accepted by the people who plan and implement and keep the books on our stewardship of the planet. I am taking the Departmental lead in developing a mission, policy, and goals for environmental education. The systems approach will underlie the efforts of all Interior agencies in this area.

If all this seems somewhat esoteric and a little far afield from the solemn purpose that brings us together, remember this: We too are part of a system; we cannot "deal in a vacuum." What we aspire to do for the good of all mankind must be done with the help of a good part of mankind.

You are the keepers of a mountain of knowledge about riparian systems--information that leads you to advise new action directions. Some of your information must become common knowledge, or action will not follow. Your basic findings must begin to be incorporated more widely in environmental education materials. We must win support for the work science does and we must communicate the products of that work. I have confidence that we will be able to do both, and I have encouraging indications to back my optimism.

On July 25th of this year, a memo from the Office of Policy and Budget at the Department of the Interior went to all heads of offices and bureaus. The subject was basic research funding. Attached were two items: One from the President's Office of Management and Budget, co-signed by the Director of the Office of Science and Technology Policy, and the other on White House stationery, signed by the President.

In no-nonsense language, the three memoranda said essentially the same thing--that it is the policy of this Administration to assure effective support for basic or long-term research. President Carter noted that "basic research had fallen far too low over the past decade" and recommended "modest increments of real growth" as necessary "to strengthen the Nation's capacity and productivity in critical areas of research."

The message from OMB acknowledged that the President's determination to reduce the budget deficit had imposed stringent ceilings on overall agency planning for fiscal year 1980-82. "Despite these tight constraints," the memorandum stated, "We believe it is important to reemphasize the Administration's concern for the funding of basic research." It goes on to iterate a policy that will "assure effective support of basic or long-term research, particularly to provide a better basis for decisionmaking or for dealing with long-term national problems."

The work we contemplate here at this symposium--the basic research in support of the management of riparian systems--is itself a part of a larger system, the socioeconomic system of this nation, and as always there is much interdependency at work. Sometimes one and sometimes the other must take precedence, but always with the goal of keeping both enterprises healthy and intact.

The tone for a systems approach to management strategies was set in May 1977, when President Carter issued Executive Orders 11988 and 11990, stating that it was Federal policy for all flood plains and wetlands and the beneficial values they contain to be protected from actions that would adversely affect or incompatibly develop them.

Furthermore, if after a thorough study it still was deemed necessary to take some adverse actions involving these areas, then a detailed explanation of why must be made, and mitigating measures must be taken.

The systems nature of natural resource management as it is evolving throughout government today, comes strongly into play in another area that impacts upon riparian systems; namely, the struggle to prevent one agency from undermining, no matter how inadvertently, the objectives of another.

Federally guaranteed insurance for homes built deliberately on flood plains--government grants for access to and development of those lovely, fleeting landforms we call "barrier islands"--these are merely two of many such former practices now being re-studied, re-thought, and re-worked at my own and other posts in the Federal establishment.

In my three-agency backyard, I can report these accomplishments:

At the Heritage Conservation and Recreation Service, an enlightened, alert eye will be turned on all grant proposals and other forms of encouragement for recreation involving riparian systems. We are attuned to the fact that water acts as a magnet to vacationists and recreationists, and we know the delicate nature of these target areas. The Director of HCRS has served notice that project grants will be considered only where the State, the municipalities, and concerned citizens have come up with a coordinated plan--one that complies with long-range environmental quality standards as well as one that serves immediate human appetites.

A study of the barrier islands, directed by the President and led by HCRS, will add to our understanding of these unique systems and of what can be done at the Federal level to keep them healthy and intact.

As part of our Nationwide Outdoor Recreation Planning process, we are examining in-depth the major issues of river protection in America. The challenge is twofold: First, to reverse the historic view that conservation of scenic, fish, wildlife, culture and recreation values along river corridors should be the exception rather than the rule; and second, to assure maximum public recreation benefits from the estimated $14 million the public is paying to make most of our rivers swimmable and fishable through water quality programs.

Our goal is to achieve a complete national river system within ten years, starting with a basic inventory of all rivers and relying on State, local, and private protection initiatives and ownership wherever possible. Maximum use will be made of existing authorities and programs, with special emphasis on coordination as a means of achieving more and worthier goals for the same effort.

In the Fish and Wildlife Service, we are acting with awareness of the monumental support job and the tenuous connections that riparian systems furnish--how much of the nourishment of estuaries depends on the continued healthy functioning of the fragile riparian ecotones, or what is left of them;

and how high a percentage of the natural plant and animal values of this continent exist only there.

At Fish and Wildlife we are moving deliberately away from species management and into systems management. For example, we have just completed, in cooperation with the National Park Service, a detailed analysis of non-game animals in the riparian habitats of the Grand Canyon as a first step in developing a model for systems management on national refuges nationwide.

I have just approved a proposal by the Fish and Wildlife Service to acquire 443,000 acres of the lower Atchafalaya River flood plain, to be managed as an Area of National Concern for flood control, fish and wildlife conservation, and recreation. The multi-purpose management plan would protect existing environmental values while still maintaining a floodway for passage of excess waters from the Mississippi and Red River drainages.

In addition, the Fish and Wildlife Service is pursuing and exploring systems approaches--through modeling, ecosystems characterizations, adaptive environmental assessment techniques, multiple objective programming, and other means.

The National Park Service, under its revitalized science program, is conducting a similar inventory of baseline data throughout the National Park System, again aimed at a systematic approach to management. A principal goal of the Natural Resources Division of NPS is to marry science information to true resource management.

As a first step, the Park Service will be emphasizing the development of sound resource management programs based on the best research data obtainable. Resource managers at the site will free the superintendent to captain his whole ship with a full set of scientific data pertaining to the park site. Informed scientific resource managers will act as liaison between scientists and land managers, and I expect that will be good news to many of you.

In addition, Park Service Director Bill Whalen has ordered his science and technology staff to undertake the testing of the energy analysis methodology described in the South Florida Report--a study I understand many of you here contributed to. Besides pointing up the intrinsic values of the resources to be preserved, the energy accounting method allows for quantification of development versus non-development alternatives, with emphasis on energy efficiency and the dollar savings that such efficiency makes possible. Into the dollar column will also go an accounting of the so-called "free" work of the systems that would be canceled out if development were allowed.

Such quantification can and will be made available to local communities where development pressures are intense and citizens are seeking to resist. Riparian systems stand to be the biggest gainers from any approach that can show an economic reason for barring development.

A whole range of real estate techniques can be tailored to the circumstances of individual cases. We are looking for those less costly alternatives to fee simple title, such as scenic easements and tax incentives, to help us protect riparian resources. Non profit, non-governmental organizations such as the Nature Conservancy have often been our advance guard and we can learn much from their example and experience.

Cooperative management is another tool, as shown with the Blackfoot River in Montana. This is not part of the national river system, but a management agreement has been negotiated among Federal, State, local, and private interests. Agreements like that can become the rule, not the exception, and the working out of such cooperative management can become part of the designation process itself.

Our prime opportunity for exemplifying this kind of action lies in Alaska. When we began looking at the job that faces us there, our first and last opportunity to "do things right," we met a Native population pleading with us to develop a natural resources data base. This we have planned and intend to do, and more.

In addition to the mere collection of data, we plan to inventory Alaska's resources in a uniform manner, (producing data in a form) suitable for interchangeable use by the various agencies responsible for natural resources management and program development.

The final step in making the most of basic research is our cooperative planning and management mode. All three of the bureaus I oversee are dovetailing their research plans for Alaska so that all known bases are covered and the data obtained are useful to those with responsibility for management.

Remember, the Natives who requested

this information base will be in possession of 44 million acres of Alaska. The decisions as to what should be developed and where it should be placed will be theirs. If we have done our job, including communicating our findings so that the information meshes with the goals and needs of the Native peoples, they will draw their homes and industries into their planning drafts in ways that respect the flows of the systems.

Our goal is to work for more of these collective approaches, and the data your work is providing will be invaluable support for achieving the new management position.

Money is the poorest tool we have, given the cosmic and systemic nature of the work we have to do. We're in the systems business, and we are moving as rapidly as possible to make our management reflect that fact.

We want to manage pro-actively, rather than re-actively. We want to improve both the systems we manage and the systems we manage with. One way to do that is to squeeze the waste out of our management and our maintenance. Too much money thrown here and there prevents rather than promotes the development of the right attitudes--of an environmental ethic.

We want to invest more in support of the natural systems we manage and less in their alteration. When we squeeze the waste out, we find our separate agencies discovering ways to work together synergistically, providing a holistic service that is greater than the sum of its parts.

We have a powerful new arsenal of tools that have yet to be fully tested--the concept of Areas of National Concern, Unique Ecosystems, the National Heritage Program, the plan for the National Wild and Scenic Rivers System, the Fishery Resources System, the Barrier Island Protection Program, and Interior's new memo of understanding with the Environmental Protection Agency.

President Carter gave us a priceless line to use when he said in his water policy statement that migiation would be a required part of all planning and implementation of water projects from now on.

You out there, and those I represent in Washington, are the pieces of a new awareness and a new application of knowledge that is slowly forming. I am pleased and proud of the support role my agencies are playing in your work, and we eagerly look to the proceedings of this symposium as another important milepost on our path to planetary stewardship.

I have a Conservation Creed that I am fond of, written by Robert Hatch, and I often use it in closing. But this has been a long speech, and its subject matter is perhaps better wrapped up by a quote from Aldo Leopold:

"Conservation is a state of harmony between men and the land. By land is meant all of the things on, over, or in the earth. Harmony with the land is like harmony with a friend; you cannot cherish his right hand and chop off his left. That is to say, you cannot love game and hate predators; you cannot perserve waters and waste the ranges; you cannot build the forest and mine the farm. The land is one organism. Its parts, like our own parts, compete with each other and cooperate with each other. The competitions are as much a part of the inner workings as the cooperations. You can regulate them--cautiously--but not abolish them... If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering."

Science and the Conservation of Riparian Systems[1]

John R. Clark[2]

Abstract.--A conservation program for riparian ecosystems is believed to be timely but difficulties of initiating a comprehensive program must be realized. The policy base for a riparian conservation program will have to be strongly supported by a set of scientific principles yet to be articulated. Where a complex ecosystem is to be managed by a complex bureaucracy, many principles have to be matched with many policies in one program. This is true whether the issue is one of lakes or streams, wetlands or floodplains, waterfowl or endangered species. The coordinative rather than conjunctive method of liaison between science and management is recommended. Principles are the essential foundation, but science must also provide the facts, functional relationships, and the cause-effect correlations for particular systems.

A focused national program for protective management of riparian systems certainly is a worthwhile and feasible cause. But the obstacles to the accomplishment of an effective program are formidable because of the extent of overlapping authorities and regional differences. In this situation the demands for research will be great. It will be a complex task to protect the functioning of riparian ecosystems of the eastern United States where so many natural processes must be known, evaluated, and sustained in a great variety of political and institutional settings. Yet it can be accomplished if the public support is there and if the plan is bold.

Before exploring the kind of national program that is needed, it is useful to consider the givens and to clarify the subject with some assumptions.

First, I will assume that there is a national interest in the protection of riparian systems and that this national interest cannot be served by actions of individual counties or states. If a systems view is taken one certainly perceives that the water moves from state to state, that rivers often form the boundaries between states, that migratory birds and fishes that belong to no state depend upon riparian systems, that riparian dependent commerce moves from state to state. Moreover, the federal government is already very deeply involved in regulatory activities that affect riparian systems and is a principal riparian landowner. Clearly, there is a strong national interest.

Second, I will assume that the interest to be served is not preservation, but conservation of riparian systems. Which is to say we agree it may not be feasible to preserve intact the whole system of which any riparian habitat is a part. That instead, our goal is to conserve the values of riparian systems by maintaining their vital processes. This would undoubtedly mean preserving many riparian habitat units intact, but allowing controlled use in others. Conservation, the wise use of resources, is a doctrine rapidly returning to popularity after living in the shadow of environmentalism for 15 years. But make no mistake, conservation is a cause and a high form of advocacy which has many supporters. Let me conclude that resource conservation should be the theme of a riparian program.

Third, I will assume that conservation of riparian systems has an effective political constituency, at least in the arid southwestern states where riparian lands are so explicit and

[1]Paper presented at the National Riparian Ecosystem Symposium, Callaway Gardens, Georgia, December 11-13, 1978

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where the conservation need is in the clearest focus. I will also assume that in other parts of the country a strong riparian constituency can be formed from the constituencies for stream protection, flood protection, nature study, wetlands, fish, game, waterfowl, and so forth. These supporters must be able to make a strong case to overcome the opposition of federal agencies, agriculture and forestry interests, water control and supply interests, and urban and industrial development boosters. Without a strong constituency hopes for a national riparian conservation program are dim.

Fourth, I will assume that the riparian concept is clear and that riparian habitat and riparian system are terms that have an unambiguous definition in the west, although the western riparian literature alternately includes and excludes marshes and hillsides (Johnson and Jones, 1977). Nevertheless, riparian habitat proper most commonly embraces only the "floodlands"; i.e., the lands above the elevation of normal annual flooding (and thus above the wetlands) and below a reasonable highest elevation of intermittent flooding (say, the 100-year flood mark). If this is so, then there is parity between west and east and we can think of western riparian lands as the equivalent of eastern "floodlands" (distinguished from "floodplains" which extend down into wetlands and up to a highest conceivable flood level, say, the 500-year flood mark) (Conservation Foundation, 1978).

Developing a definition of riparian habitat for national policy purposes will not be easy. At times it will become more of a political than a technical judgment because each interest will be bullish or bearish on the area to be dealt with depending upon whether it supports or opposes their particular program and constituency. Then, too, there is natural complexity to be dealt with. For example, here in Georgia, Charles H. Wharton, who recently published (1978) a survey of the state's natural environments, lists 15 ecologically distinctive hydric type systems associated with lotic waters. In the Lower 48 states we have three and a quarter million miles of streams and rivers (Cummins and Spengler, 1978), and perhaps 150 million acres of floodplain habitat to define and classify. It might, for the present, be better to address whole regional riparian (river) systems than to identify specific riparian habitat types for conservation purposes; that is, take a holistic rather than reductionist approach so that the concept can be as inclusive of the various regional and type systems as possible. However, the dangers of losing clear focus for the program and of massing strong political opposition lurk there. From a technical standpoint, I will assume that we <u>are</u> clear on the meaning of riparian habitat and riparian systems, and that our thrust is to focus on conserving the river-dependent or riparian plant communities of the floodlands.

Fifth, I will assume that we are clear about the values that accrue to mankind from healthy riparian systems. These will be the values that we attempt to protect in the riparian conservation program. While science is obviously far from having completed enough research to pin down many of these values, we can take stock of what we know and give our best opinions. So far riparian consciousness has been centered on biotic properties with little earnest research done to discover non-biotic values. High on the priority list should be research on values for water quality, water control, water supply, geologic stability, recreation, quality of life, and others we believe add up to the full value of riparian systems. For now though, let us assume that these values are there and if not fully delineated they will be within a reasonable time.

With these assumed conditions it is possible to formulate the ecologic principles which are needed to develop public conservation policies. If the right principles are dumped into the black box of public affairs they may come out as riparian conservation policies. A scientist needs to know something, but not a lot, of what goes on inside the box in order to make his input effective. It is important that the scientist identify the conservation constituency, who the advocates and activists are, and how most efficiently to contribute to their efforts. These activists do the work inside the black box, scientists should stay out of it to the maximum possible. The Conservation Foundation has built its environmental planning system, the Coordinate System, on the premise that science should be insulated from activism (Clark and Zinn, 1977). The reason is that adversariness is antithetical to the scientific method. Yet the development of scientific <u>principles</u> upon which conservation <u>policies</u> can be founded is not, of its basic nature, polarizing; it is a completely compatible pursuit.

Let us look at one theoretical example of the linkage of an ecological principle with a public policy for conservation of riparian systems:

> <u>Principle</u>: The natural periodicity of river flow is essential to the maintenance of best riparian system function.
>
> <u>Conservation Policy</u>: Structures shall be discouraged which alter river flow so as to cause a significant adverse impact on the riparian system.

While neither statement may seem especially exciting to the imagination, if the example policy had been in place throughout the federal agencies for the last several years our riparian systems would be in much better shape than they are today. Many other examples could be given, all of which would need extensive scientific support to become implemented.

The means by which one might get a series of such policies into place in the federal system is the next subject. The process is extremely difficult particularly because of the regional magnitude and complexity of individual riparian systems which cut across local, state, federal, and international boundaries and include public and private land holdings of all kinds. Any one riparian system may be encumbered already by dozens of conservation, water development, environmental management and economic development programs. While a new program to conserve riparian habitat might not be a welcome addition to many interests, one that sought to coordinate existing conservation activities, garner local support, and provide federal aid for planning, acquisition and administration, might be better received.

Here I am struck by the similarity of the riparian cause to the coastal cause which generated the Coastal Zone Management Act of 1972. Like the riparian cause, the coastal cause focused on the edge of the land and its interaction with water. The consciousness of the special nature of the water's edge is the force which relates the two. I believe that we can learn much from the successes and failures of the coastal cause.

Coastal zone management, as such, was never a popular cause, it was purely an invention of Congress, fashioned to respond to a number of conservation and environmental causes that were popular in 1972. When Congress passed the Coastal Zone Management Act, it temporarily relieved itself of pressures from advocates of wetlands, estuaries, beaches, oceans, science, and of national land use control. The intention of Congress was to conserve coastal resources and coastal environments by funding individual states to design and implement programs of protection, <u>if</u> they wanted to--the program is voluntary. The tie from state to federal agencies was a mutual promise to be "<u>consistent</u>" with each others programs and respect each others authorities--there are no federal substantive standards. The states conform mainly to <u>process</u> requirements. For all these reasons, coastal zone management is incapable of providing a uniform and complete program for conservation of resources of national interest along the water's edge. State programs are variously in the hand of departments of natural resources, planning, ecology, environmental protection, departments of state, or special commissions. California's program which the Conservation Foundation has analyzed is managed by a special state commission which expires soon by law, leaving coastal management in the hands of 69 local government planning departments (Healy, 1978). The best results appear to be coming from programs run by resource departments.

Science played a very active role in the coastal cause. I was one of a hundred specialists called to a two-week meeting in Woods Hole, Massachusetts, in May 1972, to work out the scientific and technical basis for coastal management. We did our job well enough we thought and the coastal zone act was passed in October 1972. This federal program was the fruit of our labor and it has been a disappointment to many of us. It turned out to be a comprehensive planning approach rather than a focused resource conservation approach. With the riparian zone we should be able to do better.

My conclusion is that the national interest in resources cannot be served by a voluntary, loose program, motivated primarily by a small federal grant. Anything like this would be a poor model for riparian conservation.

It is particularly relevant here that scientists and resource specialists were deeply involved in the cause that lead to the coastal zone act. They were involved in the same way that we are in the riparian cause. In both cases we perceived the values, collected the facts, sounded the alarms, and tried to find solutions in existing laws, programs, and administrative mechanisms. The coastal cause caught on and became popular. In the riparian context, we are so far holding meetings and symposia and we are talking to ourselves.

A current hope for riparian conservation is that by some good fortune the federal agencies, many of which have conflicting missions, will implement a comprehensive interagency program to protect riparian habitats, thus avoiding the need to go to Congress. But interagency agreements are typically the lowest common denominator, not the vehicle for bold new national initiatives. Powered by no new outside force, it seems unlikely to me that voluntary agency cooperation will accomplish the full need. But powered by an outside force, such as an "executive order" or other presidential directive, it might work. Still, this would leave dangling the problem of controlling privately owned riparian land, a serious ommission in the East where most of the riparian shore is in private ownership. It also leaves dangling the problem of publicly

owned state and local land. It seems to me that something new is needed in the way of a federal-state-local-private partnership concept. The riparian issue seems ripe for such an innovation.

I can suggest one such new concept, one which is in its infancy in the United States but has worked very well in Great Britain and other European countries (Kusler, 1974). Because it is so new, it goes by different names: conservancies, public/private parks, areas of national concern, greenline areas. Following the lead of John Banta, a colleague and expert in this field, I use "conservancy"; as does California in its version, which is an adjunct to the coastal management program. The essence of the conservancy approach is co-operative management of designated large resource areas, too large to buy the whole thing with available public funds. In essence, a compact is set up between state and local interests in each designated area. Once the area is designated, some public acquisition funds are made available to purchase fee or easement in private lands and for other purposes. There is an implicit threat of selective state or federal acquisition if the compact is broken. Local governments are brought into the program by various incentives to implement needed land use regulation of private land within the designated area. Existing government regulatory, construction, and aid programs are coordinated with the conservancy program. A major experiment at the federal level is the New Jersey Pine Barrens system, set up under the 1978 federal parks act. It will be a few years before it can be fully evaluated but the conservancy approach seems promising for conservation of designated riparian systems.

What this would mean for scientists and resource specialists is considerable work in defining and evaluating riparian habitats and riparian systems and in providing guidance on implementation of conservancy programs. But I think we are ready to lend our energy and talent to this cause.

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Structure and Function of Riparian Wetlands[1]

Sandra Brown[2], Mark M. Brinson[3], and Ariel E. Lugo[4]

Abstract.--The structure and function of flowing water (riparian) and still water wetlands were compared. Structural features (biomass, stem density, basal area, height, complexity index) for flowing water forested wetlands were shown to be similar to still water wetlands with the exception of stem density and root/shoot ratios which were considerably higher for the still water wetlands. Total biomass of nonforested wetlands was similar over all latitudes, although root/shoot ratios increased at higher latitudes. Flowing water wetlands had higher rates of gross primary productivity, respiration, litterfall, net biomass production, and organic matter export than still water wetlands, possibly due to less stressful conditions provided by water movement. The sediments of riparian wetlands have characteristics which ultimately depend upon the geomorphology of the basin. They also depend, in part, on the hydrological regime and the rate of supply and quality of source material that is delivered from upstream and within the floodplain itself. Maintenance of the natural energy inflows and the primary producers must be first priorities in wetland management to sustain the integrity of riparian ecosystems and their numerous human values.

INTRODUCTION

Wetland ecosystems have been classified in a number of ways. In a preliminary survey of the literature, we found 12 different wetland classification schemes developed for either the U.S.A. as a whole or different regions of the country. The bases for these wetland classifications were varied and included floristic composition (Pase and Layser 1977; Dick-Peddie and Hubbard 1977; Conard et al. 1977); topographic location (Meehan et al 1977); geomorphologic configuration of the basin (Lugo and Snedaker 1974); environmental parameters such as hydroperiod and/or water quality (Stewart and Kantrud 1971; Pool et al. 1972; Millar 1976; Wharton et al. 1976); or any combinations of the above plus other criteria such as latitude or plant habit (Penfound 1952; Brown and Lowe 1974; Cowardin et al. 1976).

Each of these classifications satisfies the intentions of their proponents and serves certain purposes in particular regions of the country. The effort by Cowardin et al. (1976) attempts to incorporate, under one scheme, all the wetlands of the U.S.A.; however, in the process of achieving this objective this classification loses its conceptual validity. We take the view that wetland classification efforts should be, above all, conceptually correct in order to be of maximum usefulness for management, for arriving at value judgments, and for the determination of ecological research priorities.

Coastal wetlands were classified by Odum et al. (1974) according to the intensity and pattern of delivery of all the energy flows that converged on them. The basis for this classification was that energy inputs shape the structure and function of all the subsystems of the ecosystem including the geologic, biotic, and

[1]Paper presented at the symposium on strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Calloway Gardens, Georgia, December 11-13, 1978.

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and geochemical subsystems. The sum of all the energy sources that converge on an area expressed on an equal energy quality basis was termed the energy signature by Odum et al. (1977). Building on this concept, Kangas (1978) grouped the energy signature of landscapes into four dominant categories as follows:

1. Power sheets - Energy signatures where the main component is delivered over a broad area perpendicular to the surface. Examples of these components are rainfall, sunlight, the potentiometric surface, or uniform rock substrates.
2. Power points - Energy signature where the main component is delivered in a concentrated form over a small area perpendicular to the surface. Examples of these components are artesian springs, or a localized type of substrate such as a serpentine soil.
3. Power fronts - Energy signature where the main component is delivered over a broad area as a moving force parallel with the surface. Examples of these are sheetflows of water, tides, and air masses.
4. Power lines - Energy signature where the main component is delivered over a small area as a moving force parallel to the surface. Examples are rivers, streams, or floodwaters.

Obviously, there are gradations between these four types of power spectra but we can use the scheme to separate riparian wetlands from other types.

In this symposium we are concentrating our attention on a particular type of wetland ecosystem, the riparian wetlands, which have tentatively been defined by the conveners of this symposium as follows:

> Riparian ecosystems are wetland ecosystems which have a high water table because of proximity to an aquatic ecosystem or subsurface water. Riparian ecosystems usually occur as an ecotone between aquatic and upland ecosystems but have distinct vegetation and soil characteristics. Aridity, topographic relief and presence of depositional soils most strongly influence the extent of high water tables and associated riparian ecosystems. These ecosystems are most commonly recognized as bottomland hardwood and floodplain forests in the eastern and central U.S. and as bosque or streambank vegetation in the west. Riparian ecosystems are uniquely characterized by the combination of high species diversity, high species densities and high productivity. Continuous interactions occur between riparian, aquatic and upland terrestrial ecosystems through exchanges of energy, nutrients, and species.

This definition is general enough to include most types of known wetlands. For the purpose of this paper we will narrow the definition to include only those types which are exposed to lateral water flow, i.e., those whose energy signature is influenced by power fronts or power lines. We assume that lateral water flow, when concentrated along a river channel or floodplain (a power line), becomes the main force that organizes and regulates the function of riparian wetlands including their biogeochemical cycles and their role in the landscape.

When the lateral water flow is spread over a large area (power front) its influence on the ecosystem is diluted relative to a power line. The kinetic energy of water flow, however, still provides a subsidy to wetland systems. In contrast, wetlands that lack the subsidy of lateral water flows develop different functional and structural attributes as we will discuss below.

This paper is divided into the following sections: structural characteristics of the vegetation, the functional attributes of the ecosystem, wetland geomorphology and soils, and a discussion that seeks for the interpretation of results. For the first two sections we discuss both forested wetlands and nonforested wetlands.

STRUCTURAL CHARACTERISTICS OF VEGETATION

Forested Wetlands

Table 1 is a summary of data for stem density, basal area, tree height, and tree species richness for riparian (flowing water) and nonriparian (still water) wetlands. We recognize that differences in stand age may confound comparisons, but most of the data are for reasonably mature forests. The data are arranged by latitude and by type of wetland. In general, the data show that forested wetlands are characterized by low tree diversity, high stem density, high basal area, and trees with heights in excess of 10 m. The most apparent structural difference between still water wetlands is the density of trees which is almost twice as high in the still water wetlands. In Oklahoma, Rice (1965) compared floodplain forests with upland forests and found that basal area and tree density were 2.2 and 1.3 times higher, respectively, in the floodplain. In comparing latitudinal trends, trees of northern forested wetlands appear to be shorter and have lower basal areas. It is not clear whether tree species richness increases towards the lower latitudes.

The structural indices of a forest can be combined into a complexity index calculated

Table 1. Summary of structural indices of forested wetlands in the U.S.A. All values are expressed as the mean of n stands ± 1 standard error.

Forest type	Latitude	No. of stands (n)	Stem density (#/ha)	Basal area (m^2/ha)	Height (m)	No. of stands (n)	Tree diversity No. tree species
Still water	35-50	13	2294±522[1]	34.3±4.8[1]	13.9±2.8[2]	13	5.6±1.0[1]
Still water	29-31	7	1867±399[3]	60.9±6.9[3]	21.4±4.2[3,4]	5	6.2±0.6[5]
Mean		20	2145±360	44.1±4.9	15.9±2.6	18	5.8±0.7
Flowing water	35-40	24	604±96[6]	36.9±4.1[6]	---	11	6.7±3.2[7]
Flowing water	29-33	11	1149±113[8]	53.3±6.1[8]	---	6	9.2±3.2[9]
Mean		34	791±87	41.8±3.9	---	17	7.6±2.3

[1]Bay 1969; Reader and Stewart 1972; Reiners 1972; Parker and Schneider 1974; Dabel and Day 1977; Reynolds et al. 1978a; Reynolds et al. 1978b; Reynolds et al. 1978c; Robertson et al. 1978.

[2]n=6. Bay 1969; Reiners 1972; Parker and Schneider 1974; Reynolds et al. 1978a.

[3]Hall and Penfound 1943; Applequist 1959; Brown 1978; Flohrschutz 1978; Schlesinger 1978.

[4]n=4.

[5]n=5. Hall and Penfound 1943; Brown 1978; Schlesinger 1978.

[6]Lindsey et al. 1961; Rice 1965; Schmelz and Lindsey 1965; Anderson and White 1970; Brinson 1977; Conard et al. 1977.

[7]Lindsey et al. 1961; Anderson and White 1970.

[8]Penfound and Hall 1939; Hall and Penfound 1943; Applequist 1959; Conner and Day 1976; Brown 1978.

[9]Penfound and Hall 1939; Hall and Penfound 1943; Conner and Day 1976; Brown 1978.

from the product of tree diversity, basal, area, stem density, and tree height for trees with DBH ≥ 10 cm in 0.1 ha plots (Holdridge et al. 1971). Complexity indices were calculated for forested wetlands where sufficient data were provided by the authors (Table 2). However, Holdridge's formula was modified to include all tree species with a DBH ≥ 2.54 cm. All the forests in Table 2 are communities that have one or two dominant tree species. In general, the wetlands at lower latitudes have the highest indices and there is little difference between the still water and flowing water wetlands. Using trees with DBH larger than 10 cm, we calculated complexity indices of 27 and 68 for floodplain forests in Indiana (Lindsey et al. 1961; and assuming a tree height of 24 m). In Florida, Brown (1978) found indices of 34-105 for still water cypress wetlands (for DBH ≥ 10 cm). For comparison, complexity indices (using DBH ≥ 10 cm) for floodplain forests in Costa Rica with short hydroperiods ranged from 186 to 351, and for those with long hydroperiod and stagnant water they ranged from 27 to 135 (Holdridge et al. 1971). Thus, it appears that increased flooding and decreased water flow in tropical wetlands is associated with decreased structural complexity of the forest. However, in comparing the Florida and Indiana examples, the higher structural complexity develops with longer hydroperiod; the same trend is observed with the complexity indices shown in Table 2 (DBH ≥ 2.5 cm) where those wetlands at lower latitudes had longer hydroperiods.

Table 2. Complexity indices of forested wetlands in the U.S.A.

Forest Type	Complexity Index[1]	Source
Still water wetlands		
Cedar Swamp; MN	99	Reiners 1972
Atlantic white cedar swamp; NJ	106	Reynolds et al. 1978a
Cypress domes; FL	98-300	Brown 1978
Cypress domes (mature); FL	391	Ibid
Dwarf cypress; FL	6	Ibid
Tupelo gum-cypress-swamp black gum; AL	175	Hall and Penfound 1943
Okefenokee Swamp; GA	55-223[2]	Schlesinger 1978
Latitude 35-50	61	From Table 1
Latitude 29-31	150	From Table 1
Flowing water wetlands		
Cypress Strand; FL	77	Nessel 1978
Tupelo gum; AL	58	Penfound and Hall 1939
Floodplain forest; FL	88	Brown 1978
Cypress swamp; IL	13-16[3]	Anderson and White 1970
Latitude 35-40[4]	30	From Table 1
Latitude 29-33[5]	141	From Table 1

[1]Complexity index = $\frac{\text{basal area x stem density x height x number of species}}{1000}$ for all trees species with a D8H ≥ 2.54 cm in 0.1 ha plots.

[2]For trees with D8H ≥ 4 cm.

[3]Height was taken from Mitsch et al. (1977) for the same wetland.

[4]Assumed height of 20 m.

[5]Assumed height of 25 m (Penfound and Hall (1939) reported a height for a tupelo forest of 32 m and Brown (1978) reported a height for cypress floodplains of 17 m).

Data on the biomass of forested wetlands are summarized in Table 3. The aboveground biomass of still water and flowing water (floodplain) wetlands range from the lowest to the highest values reported for temperate upland forests. Although the flowing water wetlands tend to have a higher biomass than still water wetlands, it is difficult to draw conclusions from these comparisons. The lowest aboveground biomasses that we report tend to be associated with the more northern forests. However, the most southern wetland forest (dwarf cypress) has an aboveground biomass comparable to the northern bog forest. This demonstrates how different stressors have similar effects on structure regardless of latitude.

Root biomass data are rather limited, and the few values reported range widely from 0.3 to 9.6 g/m^2 (up to depths of approximately 30 to 200 cm). Ratios of belowground biomass to aboveground biomass (expressed as percentages) may be more valid indices for comparison and were calculated from data provided by the authors. Ratios were 51% for a spruce bog forest (Reader and Stewart 1972), 22% for dwarf cypress (Brown 1978), 18% for a cypress strand in north central Florida (Nessel 1978); and 3 to 4% for cypress strands in south Florida (Burns 1978). Dwarf forests growing in still water conditions appear to allocate a larger proportion of their total biomass to roots. Since bogs are typically low in nutrients (Heilman 1966; Small 1972) and the dwarf cypress forest was found to be very infertile (Brown 1978), the relatively high root biomass is possibly an adaptation to facilitate nutrient cycling in the nutrient poor environment. For example, Odum (1970) suggested that the dense root mats in cloud forests serve the same function and were an adaptation to high rainfall and low nutrients.

Understory biomass is generally low for all wetland forests (Table 3) and is particularly low for those forests subjected to extreme flooding regimes. Apparently, shrub or herb species are poorly adapted to submergence.

Nonforested Wetlands

The data for marsh ecosystems were hard to arrange according to the scheme presented for forested wetlands. Stands were thus classified according to water fluctuation when such information was available. The tendency in nonforested wetlands is towards monospecific stands. However, low water-fluctuating marshes appear to have a greater diversity than high water-fluctuating marshes (Table 4).

Most of the data on biomass are for aboveground parts only (Table 4). A comparison of the aboveground biomass suggests that there is a general trend of increasing biomass at lower latitudes as was for the forested wetlands. For example, McNaughton (1966) found a three-fold increase in *Typha latifolia* biomass at latitude 30°N compared to latitude 48°N. The lowest aboveground biomass reported is for a system located in the subarctic (290 g/m^2; Wielgolaski 1975). A mean total peak biomass (above and belowground) of 1578 $\pm$ 511 g/m^2 (7 sites) was calculated for the marsh systems below 35° latitude and was comparable to a mean of 2041 $\pm$ 250 g/m^2 (21

Table 3. Biomass of forested wetlands in the U.S.A. Values are expressed as the mean of n stands $\pm$ standard error.

Forest Type	Location (latitude)	No. of stands (n)	Aboveground tree biomass (kg/m^2) Mean	Range	n	Understory biomass (g/m^2) Mean	Range
Still water	26-50	16	19.1$\pm$2.7[1]	3.6-34.5	9	173$\pm$51[2]	24-238
Flowing water	29-43	5	26.0$\pm$7.5[3]	2.8-45.3	4	132$\pm$53[4]	20-276

[1]Reader and Stewart 1972; Reiners 1972; Parker and Schneider 1975; Dabel and Day 1977; Brown 1978; Florschutz 1978; Reynolds et al. 1978a; Reynolds et al. 1978b; Reynolds et al. 1978c; Schlesinger 1978.

[2]Reader and Stewart 1972; Reiners 1972; Parker and Schneider 1975; Dabel and Day 1977; Schlesinger 1978.

[3]Tilton and Bernard 1975; Conner and Day 1976; Mitsch et al. 1977; Brown 1978.

[4]Tilton and Bernard 1975; Conner and Day 1976; Mitsch et al. 1977.

Table 4. Biomass and plant diversity of nonforested wetlands in the U.S.A. Mean, standard error, and number of stands (in parenthesis are given).

Marsh type	Aboveground peak biomass (g/m^2)	Belowground peak biomass (g/m^2)	Number of species per m^2
Low water-fluctuating			
below lat. 35	967±268 (7)[1]	---	---
above lat. 35	802±105 (3)[2]	1900 (1)[3]	6.8±0.6(4)[4]
High water-fluctuating			
below lat. 35	---	---	---
above lat. 35	942±138 (10)[5]	1744±873 (3)[6]	4.0±0.5 (6)[7]

[1]Boyd 1969, 1970 and 1971; Boyd and Hess 1970.
[2]McNaughton 1966; Van der Valk and Davis 1976.
[3]McNaughton 1966.
[4]Van der Valk and Davis 1976.
[5]Penfound 1956; Bray et al. 1959; McNaughton 1966; Mason and Bryant 1975; Auclair et al. 1976; Van der Valk and Davis 1976.
[6]Bray et al. 1959; McNaughton 1966.
[7]Auclair et al. 1976; Van der Valk and Davis 1976.

sites) calculated for the marsh systems above 35° latitude. (The means were calculated from data given in a literature review by Brinson et al. 1978). This suggests that the total biomass for marsh ecosystems is relatively constant over all latitudes. The ecosystems in the north appear to store more biomass in the belowground organs as an adaptation for survival through long winters. The highest root to shoot ratio that we found (4.5) was reported for the wet meadow system in Norway (Wielgolaski 1975).

FUNCTIONAL ATTRIBUTES OF THE ECOSYSTEM

In Table 5, we have summarized available data on the gross primary productivity, 24 hour respiration, and net aboveground biomass production for flowing and still water wetlands. Gross primary productivity, its total solar radiation use efficiency, and 24 hour respiration rates are higher in flowing water wetlands than in still water wetlands. Differences between forested and nonforested do not appear significant, although the data for forested flowing water wetlands are not sufficient to arrive at a conclusion. Above-

Table 5. Gross primary productivity, 24 hr respiration, and net aboveground biomass production of forested and nonforested wetlands. The values are means of data given in Brinson et al. (1978). Numbers in parenthesis represent number of stands on which means are based.

Forest type	Gross primary productivity ($g/m^2 \cdot day$)	24 hour respiration ($g/m^2 \cdot day$)	Net aboveground tree biomass production ($g/m^2 \cdot year$)
Still water forested wetlands	14.8±5 (6)	14.4±4.2 (6)	764±141 (10)
Still water marshes	14.6±5 (3)	10.6±2.7 (3)	---
Flowing water forested wetlands	52.1 (1)	49.9 (1)	1074±123 (8)
Flowing water marshes	30.6±7.3 (6)	20.7±4.7 (6)	---
Low water-fluctuating marshes	---	---	882±283 (7)
High water-fluctuating marshes	---	---	1091±123 (9)

ground net biomass production appears to be higher in the flowing water wetlands than in the still water wetlands. The trend for nonforested wetlands suggests a decrease in the rate of aboveground biomass production with a reduction of water fluctuation.

In terms of cycling processes, flowing water wetlands are open systems that depend upon net imports of nutrients from rivers while periodically exporting organic material to downstream ecosystems. Inputs of phosphorus into riparian wetlands have been measured by Brown (1978) in Florida and by Mitsch et al. (1977) in Illinois. Both studies found net imports of phosphorus (3.2 and 3.6 g $P/m^2 \cdot yr$, respectively), and both found the sediments to be the largest phosphorus sink (92 and 93% of the total phosphorus inventory, respectively). Relatively high rates of phosphorus cycling were measured by Mitsch et al. (1977) in the forest floor where phosphorus cycled rapidly between sediments, the water column and understory plants, especially aquatic floating plants such as duckweed. In an alluvial swamp in North Carolina, Holmes (1977) reported that transfer rates of phosphorus from the surface waters to the sediments were 1.90, 0.77 and 0.53 kg/ha·day for the spring, fall and winter seasons respectively. Although the uptake by sediments due to biological factors was not significant in the winter, it accounted for 12% to 50% of the movement in other seasons.

Litterfall accounts for 50 ± 3% (7 stands) of the aboveground tree biomass production of forested wetlands. About 80% of the litterfall is comprised of leaves (Brown 1978). The data available (Brown 1978) show a higher rate of litterfall in flowing water than in still water wetlands (563 ± 56 $g/m^2 \cdot yr$ (5 stands) vs. 468 ± 73 $g/m^2 \cdot yr$ (7 stands)).

Reviewing the literature, Brinson et al. (1978) found that litter decomposition rates varied significantly between the still water wetlands of northern latitudes and all other wetlands at lower latitudes. They found a mean annual decomposition coefficient of 0.3 in the northern wetlands vs. 0.9 for southern wetlands. The data available, however, cannot clarify if flooding frequency and duration are major determinants of decomposition rates.

The litter that is not decomposed is available for export to downstream ecosystems. Brinson et al. (1978) surveyed the literature and found that the waters of rivers with riverine wetlands carried more dissolved organic material than those of rivers without wetlands. For example, in 10 watersheds with riparian wetlands the average dissolved organic carbon concentration was 15.8 ± 0.4 mg/l while in seven watersheds without wetlands the respective value was

3.2 ± 0.4 mg/l. These organic substances become important energy sources for riverine, estuarine, and oceanic waters (Lugo and Snedaker 1974; Meehan et al. 1977). Hubbard (1977) and Hubbs et al. (1977) reported that the riparian wetlands of the southwest support a variety of fish species that are totally dependent on the riparian wetland ecosystem.

The magnitude and timing of organic exports from wetlands cannot be expected to be equal for all types of wetlands and must be expected to vary with the intensity and frequency of flushing. A riparian wetland, because of its proximity to flowing water, should export a larger fraction of the detritus it produces than a still water wetland that is flushed less frequently. Yet, because the detritus stays in the still water wetland for a longer time, there is more opportunity for microbial action, and thus its quality in terms of the C/N ratios may be higher at the time of export. For example, Fell (personal communication) has found that when red mangrove leaves fall, they have C/N ratios of about 100, but litter inside a forest with a slow turnover rate have ratios as low as 20. Thus, both the quality and magnitude of detritus exports must be considered when making determinations of the importance of detritus export from wetlands.

It is generally assumed that forests transpire large quantities of water. This might be considered especially so for forested wetlands where the soil is saturated for many months of the year. However, results do not support this assumption. For example, water budget calculations for perched still water cypress wetlands in central Florida showed that their annual evapotranspiration ranged from 83.6-88.9 cm/yr (Heimburg 1976), and for a cypress floodplain forest in southern Illinois annual evapotranspiration rates of 72.8 cm/yr were found (Mitsch et al. 1977). As evapotranspiration is related to atmosheric conditions, a useful index for comparison purposes is to express evapotranspiration as a ratio to pan evaporation (evaporation from a standard class A land pan). The evapotranspiration ratios were 0.54-0.58 for the perched cypress wetlands (Heimburg and Wang 1976) and 0.57 for the Illinois floodplain (Mitsch et al. 1977). These ratios are considerably lower than 0.7-0.8 commonly found for open water systems (Veihmeyer 1964).

Average daily summer transpiration rates from a cypress dominated floodplain forest in central Florida were 5.6 mm/day (Brown 1978) which is lower than the 9.0 mm/day (for May-June) found by Tromble (1972) for a riparian mesquite stand in Arizona and the 11.2 mm/day (for July-September) found by Sebnik and Thames (1967) for a salt cedar stand in Arizona. However, part of this difference between the two regions can be attributed to differences in atmospheric vapor pressure deficits, which are generally greater for the southwestern U.S.

Anothern important function or riparian wetlands is their role in supporting wildlife. This is particularly significant in the arid southwest where wildlife cover is more limited (Hubbard 1977; Johnson et al. 1977). Anderson and Ohmart (1977a,b) and Anderson et al. (1977) have shown that the abundance of wildlife in this ecosystem is not a function of edge effect but rather of the complexity of the vegetation, its high productivity and abundant food supply, and higher carrying capacity. They have also related vegetation structure to avian use and partitioning of the habitat. Part of the food supply for vertebrates in these ecosystems is the high abundance and diversity of insect populations that are typical of wetland ecosystems (Anderson et al. 1977; Judd 1949, 1953, and 1960; Witter and Croson 1976; McMahan and David 1977; Florschutz 1978).

RIPARIAN GEOMORPHOLOGY

As suggested in the beginning of this paper, structural and functional features of ecosystems may segregate according to the energy signature of the landscape. Riparian systems result from the geomorphological activity on these landscape features. If the geologic forces that shape and mold wetlands are considered, it is apparent that many wetland types are rather dynamic features of the landscape and are constantly in a state of flux and transition. Some of these changes have taken place during Recent times. Russell (1967) cited an example for the Mississippi valley where the Arkansas River abandoned its old floodplain which extended southward to Louisiana. When this floodplain became sufficiently alluviated, the Arkansas River developed a much steeper gradient by cutting eastward across the northern part of the old alluvial cone. This floodplain, which was abandoned only in Recent times, has relict natural levees, remnant channels, and backswamp basins that still dominate its surface. These features are now developing soil profiles and other soil properties in common with uplands with subaerial weathering. Thus, many upland ecosystems have historical affinities with wetlands that can be recognized only after careful scrutiny.

Glacial and interglacial periods during the Pleistocene have resulted in corresponding changes in sea level which are ultimately responsible for the patterns of geomorphic processes. Alternating episodes of valley cutting and filling have occurred, with erosion predominating

during lowering of sea level followed by a period of deposition during sea level rise. The oldest depositional features that correspond with the last glacial retreat are now buried toward the outer edge of the continental shelf.

Riparian ecosystems, as they currently exist, can be visualized as being located along an idealized concave profile running the length of a river valley. The upper section at the river's source, because of its steep slope, is completely erosional and floodplain development is negligible. Near the middle section a narrow, but distinct, floodplain is deposited from materials carried from upstream. In the lower section, where the gradient is least, floodplain width reaches maximum development near the sea. Along this downstream gradient, the ratio of erosion to deposition decreases, as a combined result of decreasing slope and increasing suspended load of the river.

Although the overall process is one of erosion or downcutting, this trend can be reversed owing to changes in sediment supply and in base level. For sediment supply, increasing erosion of uplands due to poor agricultural practices and forest clearing in any of the sections will increase the supply of suspended sediments and depositional material to the sections below. The energy required for carrying additional sediment is diverted from that normally allocated for erosion. The base level toward which erosional downcutting progresses may change due to events occurring at the mouth of the river. For example, the contemporary eustatic rise in sea level (11-12 cm/100 yr) will decrease the gradient and simultaneously lower the capacity of the river for downstream transport of materials. The result of this decreased gradient will be development of areas with poorer drainage and greater potential for deposition of materials transported from upstream. Projects such as channelization and levee building will tend to stabilize or reverse this trend. These activities eliminate some of the protective attributes assigned to riparian wetlands that are a function of the coupling between the river channel and floodplain soils, vegetation, and hydrologic features (see Wharton and Brinson, this volume).

WETLAND SOILS AND SEDIMENTS

The soils and sediments of riparian wetlands have characteristics that depend, in part, on the hydrological regime and the rate of supply and quality of the source material that is delivered from upstream and within the floodplain itself. Forested wetland soils and sediments range in texture from coarse sands to deep peat deposits. Considering the diversity of soil types that fall within these extremes, it is not surprising that wetland ecologists have failed to arrive at a comprehensive and uniform approach that logically arranges wetlands with respect to their soil and sediments and their origins. The normally used parameters of soil organic content, nutrient concentration, particle size distribution, etc., vary greatly among and even within wetlands.

The potential and kinetic energy of water flow is essential not only as a source (by erosion) of a river's suspended and bed load, but also for its transport to downstream floodplains. The relationship of erosion, transportation, and deposition to water velocity and particle size is shown in figure 1. The longitudinal and lateral gradients of the potential energy of water flow in riparian ecosystems can be visualized as decreasing toward the bottom of the graph, i.e., from the river source to its mouth and from the river channel to the floodplain interior. Particle size of floodplain sediments will sort according to the velocity of currents. The lateral gradient is supported by data from the Raritan River floodplain (Table 6) which show a progressive percentage decrease in sand and increase in silt toward the floodplain interior (Wistendahl 1958). A similar but less pronounced gradient of particle size distribution is illustrated by the Missouri River floodplain (Table 6).

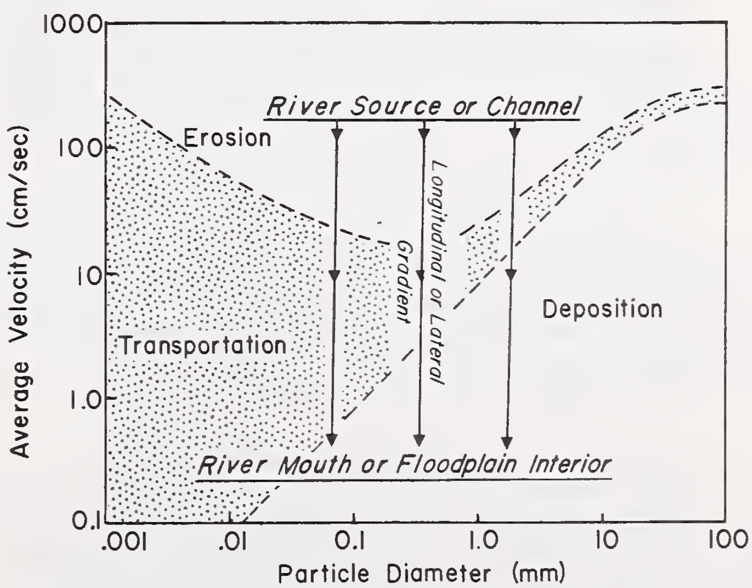

Figure 1.--The relationship between current velocity and particle size which determines whether erosion, transportation, or deposition will occur (from Hjulstrom 1935). Superimposed on this are two gradients of the kinetic energy of water flow in riparian systems. These decrease from the river source to its mouth (longitudinal) and from the river channel to the floodplain interior (lateral).

Table 6. Soil characteristics for several wetland types.

Wetland types and locality	Site description (stand age)	Sample depth (cm)	Sand/silt/clay (%)	Organic matter (%)	Exchangeable K+Ca (meq/100g)	Comments	Source
Arid riparian							
Cottonwood stands, Missouri River, SD	Riverwash (10yr)	0-15	94/4/2	0.4	---	<1m Height	Wilson 1970
	Riverwash (14yr)	0-15	89/7/4	0.4	---	2m above sum-	
	Riverwash (23yr)	0-15	86/9/4	0.8	---	3m mer river	
	Floodplain(35yr)	0-15	73/22/5	1.2	---	5m level.	
	Floodplain(55yr)	0-15	80/14/6	1.8	---	6m	
Alluvial wetlands							
Forest and marsh, Raritan River, NJ	10m from river	surface	75/20/5	---	---	Natural levee	Wistendahl 1955
	80m from river	surface	45/40/15	---	---	Field	
	170m from river	surface	25/60/15	---	---	Marsh	
Hardwood wetlands north central FL	Deciduous hardwoods	15-30	---	---	41	Average of 23 sites	Monk 1966
Floodplain forest Santee River, SC	---	surface	35/20/45	22	17	---	Priester and Harms 1971
Bottomland forests, Coastal Plain, NC	Streamside forests	0-20	---	17	10	Average of 14 sites	Snyder 1978
Floodplain forest, Mississippi delta	Willow oak stand	0-15	---	---	25	Alligator clay soil	Kennedy 1970
Floodplain forest, FL	Cypress forest	0-20	---	5	---	Natural levee	Brown 1978
				7	---	20m from levee	
				11	---	40m from levee	
Still water wetlands							
Hardwood forest, Coastal Plain, SC	Blackgum stand	surface	50/30/20	18	4.4	Still water	Priester and Harmes, 1971
Cypress domes, FL	---	0-20	---	22	---	Average of 4 sites	Brown 1978
Peat bogs							
Raised bogs, NC	Shrub peat	0-20	---	55	1.7	Average of 25 sites	Snyder 1978
Blanket bog, U.K.	Sphagnum peat	10	---	97	5.4	---	Gore and Allen 1956
Rich fen, MI	Shrub and sedge peat	0-20	---	71	53	---	Richardson et al. 1978

In contrast, still water wetlands lack the fluvial energy for sediment transport; the soil particle size distribution in these systems is probably more indicative of composition of the parent material than any sorting action.

It should be emphasized, however, that the biotic components of wetland ecosystems may greatly modify soil properties, particularly organic matter production and the recycling and conservation of nutrients. This is illustrated in figure 2 by plotting biogenic accumulation rate against deposition rate due to geologic forces (fluvial and aeolean) discussed above. This separates wetland soils according to their organic and inorganic composition by delineating predominately inorganic sediments, peat deposits, and a mixture or organic and inorganic materials. Increasing water turnover (flux/storage) is shown progressing from low values in peat deposits to high values for sediments that are mostly inorganic. Thus, the balance between the geologic force (fluvial deposition) and the biotic modifier (organic matter accumulation) is a function of the kinetic energy of water flow.

The data for soil organic matter in Table 6 support this arrangement. At extremes in organic matter content are the arid riparian cottonwood stand with about 1% organic matter and the peat bogs with greater than 50% organic matter. The alluvial wetland in South Carolina (22%) and the bottomland forest in North Carolina (17%) are intermediate and fall in the "mixed" category (fig. 2). Although there has been no attempt to quantify the rates of deposition, the percentage composition nevertheless represents the net balance of biogenic and fluvial deposition.

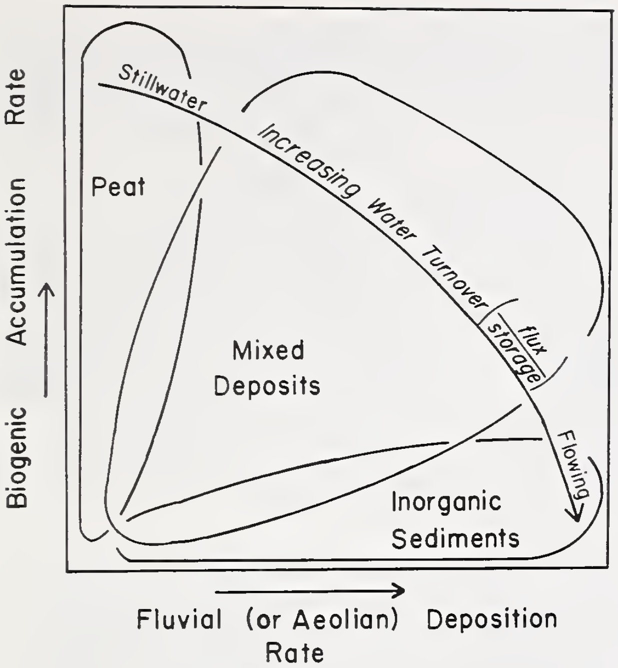

Figure 2.--Organic and inorganic composition of wetland soils and sediments as a function of biogenic deposition rate and fluvial or aeolean deposition rate. Water turnover is shown as increasing from peat deposits (still water) to inorganic alluvial sediments (flowing water).

The arid riparian system deserves mention because its sandy "deposits" are aeolean in addition to fluvial origin. This phenomenon has also been described for the South Canadian River, Oklahoma (Moore 1925, Hefley 1937). In these systems, wind partially substitutes for water flow as the energy source for erosion and transportation from adjacent uplands. On the other hand, the biogenic deposition in peat bogs is an extreme example where outside forces play a negligible role such that existing conditions are governed by biotic entities. Understanding the manner and extent to which these biotic and geologic forces are balanced and interacting appears essential to arriving at a comprehensive and uniform approach for describing riparian wetland soils and sediments.

DISCUSSION

Structure of Wetlands

We differentiated wetland ecosystems in this paper according to the nature of the dominant component of the energy signature into two categories: flowing water (exposed to power lines and power fronts) and still water wetlands (exposed to power sheets and power points). Structural indices suggest that flowing water wetlands develop structural complexity similar to that of still water wetlands. Tree density is an exception as flowing water wetlands exhibit lower tree densities. The biomass of these forests ranges widely, and no clear pattern can be established. Root biomass values are high and represent a significant portion of the total biomass, particularly in nutrient poor and still water environments. Structural indices suggest more complex development in lower latitudes. For nonforested wetlands there is a trend toward higher biomass in those with highly fluctuating water regimes as compared with wetlands exposed to lower water fluctuations. Some latitudinal trends in the structure of nonforested wetlands were similar to the trends observed for the forested wetlands.

Comparison of Riparian Wetlands from the Southwestern and Southeastern U.S.A.

The main difference between the riparian wetlands of the southeastern U.S.A. and those of the southwestern part of the country is the sharpness of vegetation zones in the southwestern part and the contrast between wetland vegetation and the adjacent xerophytic ecosystems. In the Southeast, vegetation zones are wide in comparison, and humid climates allow for a broader ecotone with upland vegetation. Meehan et al. (1977), Kennedy (1977), and Conard et al. (1977) describe the sharp vegetation gradients in the riparian wetlands of the Southwest (Table 7). However, the riparian zone dominated by Populus exhibits a basal area and canopy height comparable to any floodplain or bottomland forest in the southeastern U.S.A. (Table 1). Soil properties differ greatly and ultimately depend upon the force of water flow which results in differences in relative rates of supply of organic and inorganic material in each case.

The energy signature of southwestern U.S.A. riparian ecosystems probably approximates a power line which is the cause of the sharp and narrow vegetational zonation. In the Southeast, water spreads out more evenly

Table 7. Structural features of various zones of a California riparian ecosystem. All data are from Conard et al. (1977).

Vegetation Zone	Canopy height (m)	Tree Cover (%)	Tree Density (#/ha)	Basal Area (m^2/ha)
Valley Oak woodland (Quercus lobata)	15-20	30-60	124	18.4
Riparian forest (Populus fremontii)	30	20-30	250	50.0
Grover bar thicket (Salix hindsiana)	3-5	95	---	----
Open floodplain communities (various exotic shrubs)	1	5-25	---	----
Hydric communities	-----------Aquatic vegetation----------			

through the older floodplains and thus supports broader vegetation zones. Both types are riparian because both are exposed to lateral water flows and thus share the common properties associated with this energy signature.

Function of Wetlands

The functional attributes of wetlands show significant differences when flowing water and still water types are compared. For example, flowing water wetlands (forested or nonforested) have higher rates of gross primary productivity, 24 hour respiration, and aboveground net biomass accumulation than still water wetlands. Rates of litterfall and of organic matter export appear to be higher in flowing water than in still water wetlands. The quality of the detritus exported, however, may vary in proportion to its detention time in the wetland. Mineral cycles of both types of wetlands are open and generally involve the input of nutrients from external sources. Decomposition rates are correlated with latitude and increase towards the lower latitudes. Water loss from riparian wetlands may be high during the growing season but on an annual basis it appears to be about 50 to 60% of water loss that occurs from open water. Removal of riparian vegetation in the Southwest has been considered by some as a method of increasing available water to this region. Yet the basis for this action does not take into consideration the annual water balance. In the Southeast wetlands conserve water as a result of their leafless condition during the dormant period. In spite of this, Maddox (1972) showed that the economic value of the water gained by removal of riparian vegetation did not equal the value of the wildlife loss. Flowing water wetlands, including those of the arid southwestern U.S.A., support a high diversity and quantity of invertebrates, fish, waterfowl, and other wildlife.

These findings may be interpreted in light of the forces that converge on the wetland ecosystem. Water movement is the main force that separates the two groupings, still water and flowing water, of this paper. The longitudinal and lateral gradients in riparian ecosystems provide a spectrum of conditions that are proportional to water flow. Lack of water movement has important implications for the conditions to which wetland plants and animals are adapted. When waters are still, there is a greater probability of fluctuating water quality and lags that are stressful to organisms. Examples are the rapid depletion of dissolved oxygen, lowering of redox potentials, accumulation of toxic substances such as CO_2, reduced organic and inorganic compounds, and so on. Still water wetlands also have less opportunity for importing nutrients and sediments from outside and exporting organic products from the ecosystem. These conditions may slow down ecosystem processes. Higher stem densities noted for still water wetlands may be a compensating factor which provides greater stem surface area for atmospheric diffusion to the oxygen poor environment that surrounds roots. Still water wetlands, because they lack the fluvial energy for transportation of materials from upstream, will tend to accumulate mostly organic matter.

Under flowing water conditions all the above trends are reversed such that environmental conditions of the water and sediments tend to be more constant in the presence of flow. For example, dissolved oxygen concentrations remain fairly constant; roots and sediments are ventilated; redox potentials are higher; reduced substances, gases, and toxic substances are all removed much faster; and organic substances are exported. A greater proportion of sediments and nutrients will be derived from inorganic material transported from upstream, thus providing a nutrient subsidy for the riparian environment. Plants grow with more vigor under these conditions (Hook et al. 1970).

Implications for Management

Human impacts on wetland ecosystems may result in a variety of stresses. However, managerial techniques must be combined with these manipulations to obtain yields and services from the wetlands. Lugo (1978) suggested that the sensitivity of ecosystems to stressors varies according to which component of the ecosystem is stressed. Figure 3 is a simplified model of a wetland ecosystem that shows three structural components, energy flows amongst these components, and the external forces that affect the ecosystem's structure and function. We suggest in the diagram that human interventions are serious stressors when they alter the natural energy inflows that power the wetlands and/or significant fraction of the producer component. In these cases the ecosystem, because its environment has been changed or its productive capacity seriously impared, has no ability for recovery. Under these conditions mitigation is impossible. Human interventions that alter animals and microbes and/or a small portion of the biomass of the system may have less serious impacts on the system because the natural conditions that support the vigor and

the high primary productivity of the wetland have not been directly affected. Under these conditions mitigation is possible within certain limits.

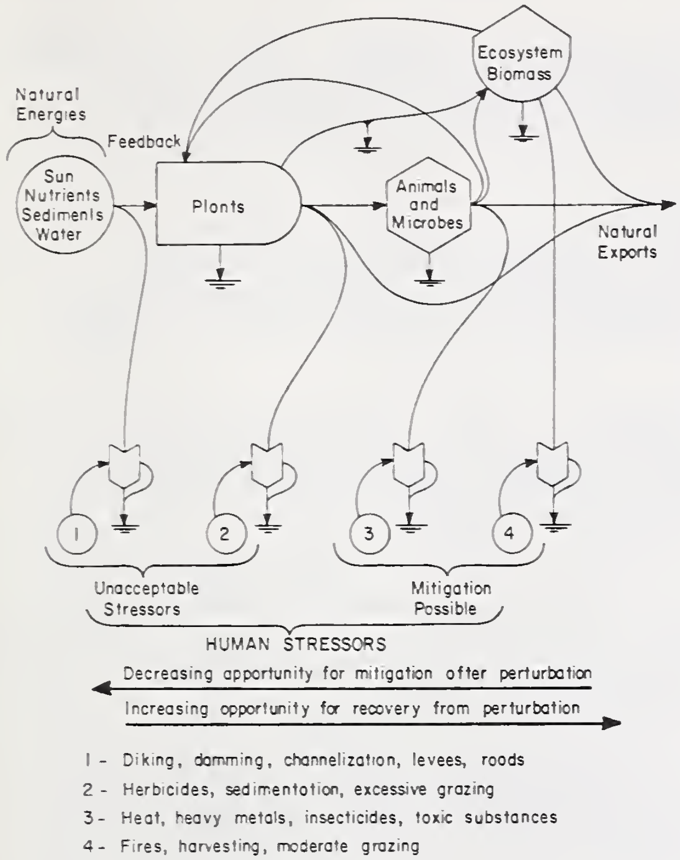

Figure 3.--Simplified diagram of a wetland ecosystem showing the interaction between stressors and ecosystem components.

According to this scheme and the literature review, a riparian wetland is highly productive and can sustain a considerable harvest of biomass as long as the physical forces responsible for the high rate of energy flow and productivity remain intact. When these forces are altered (i.e., by diking, damming, channelization, levee building, road construction, herbicide accumulation, sedimentation, and excessive grazing; see fig. 3) the ecosystem loses its vigor and rapidly deteriorates. Therefore, the cardinal rule of riparian ecosystem management is to protect the external forces that regulate the ecosystem. If this rule is followed humans will continue to reap the many benefits that they normally receive from these ecosystems.

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Characteristics of Southeastern River Systems[1]

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and

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Abstract.--Southeastern riparian systems include alluvial rivers, blackwater rivers, and spring-fed streams. Each of these types can be further subdivided based on their hydrologic peculiarities. There are many examples of strong coupling between the physical and biologic attributes of river channels and their floodplains as well as upstream-downstream sectors of riparian systems. This coupling depends on periodic pulses of water flow which are vital to primary and secondary productivity.

INTRODUCTION

We will attempt to show how southeastern stream and river systems vary in their chemistry, hydrology, floodplain characteristics, primary productivity, structure of consumer communities, and waste processing capabilities. Each portion of the length of a river, as well as its tributaries, has vital hydrologic and biologic attributes that couple the systems both longitudinally (upstream-downstream) and laterally (river-floodplain). The longitudinal effects often extend to and have profound impacts on coastal marine ecosystems.

RIVER TYPES AND HYDROLOGY

A complex of stream types has been recognized for southeastern rivers for Georgia (Wharton 1977) and Florida (Wharton et al. 1977). Most of these are listed in Table 1. All Piedmont streams are classified as "alluvial rivers" (carrying sand, silt, clay) and they continue across the Coastal Plain, contributing these sediments to their floodplains and ultimately to coastal zone islands, salt marshes, and estuaries. The "blackwater rivers" are strictly Coastal Plain streams normally low in sediment load. Another type common in Florida is the "spring-fed stream" that has clear, alkaline flow issuing principally from underground aquifers in limestone. A prominent subtype of the alluvial river is the "tidewater river"; its normal hydrology is modified daily by tidal flow, often augmented by storm and spring tides. Yet another subtype is the "blackwater stream" where the level of the main river controls the level of the tributary. These are "water dam" systems, where damming is by tides on one hand, and river flow levels on the other.

All these river types are fluctuating water level ecosystems--their high flows brought about by winter-spring rains (peak flow is in summer in Florida), their low flows correlate with high evapotranspiration during the late summer and dry fall months. The life on the floodplain as well as in the river itself is adapted to and dependent upon these natural fluctuations. Rivers and their floodplains form geo-hydrobiological partnerships. High energy mountain rivers have irregularly flooded and narrow, uncommon floodplains. Piedmont streams have wider floodplains alternating with shoals and high water covers the floodplain on and off over a six-month period. Coastal Plain alluvial rivers "smooth out" the Piedmont flood peaks into a continuous six-month inundation over broad, contiguous floodplains. Blackwater streams have narrower, less continuous floodplains and depend on local rainfall for their hydroperiod. Floodplains have a variety of topographic features:

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[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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Table 1.--Physical-chemical data summarized for Georgia streams in water year 1977 (USGS, 1977) and for natural and channelized blackwater streams in North Carolina (Kuenzler, et al., 1977). Figures in parentheses are numbers of streams for which data were averaged.

	TOC (mg/ℓ)	pH	Hardness (Ca, Mg-mg/ℓ)	Specific Conductance (μmho/cm)	Total Nitrite + Nitrate N (mg/ℓ)	Total Phosphorus (mg/ℓ)
Mountain River	1.8(2)	6.6(2)	3.5	16(2)	<.04(2)	<.02(2)
Alluvial River-Piedmont	2.9(6)	6.9(6)	12-18(4)	48-83(6)	.14-.50(3)	.06(3)
Alluvial River-Coastal Plain						
Ocmulgee-Oconee	4.1(2)	7.2(2)	18-33	68-122	.09-.38	.08(2)
Flint (Newton)	5.5	7.5	30-50	84-144	.34-.63	.06
Altamaha (Everett City)	7.9	6.6	13-33	60-191	.02-.55	.07
Blackwater River						
Tifton Plateau Type						
Ogeechee (Oliver)	8.1	6.9	12-28	47-104	<.18	.04
Canoochee (Claxton)	13.2	5.6	6-11	35-57	<.08	.06
Tallahassee Plateau Type						
Ochlockonee	9.0	7.0	11-56	49-327	<1.7	.32
Pleistocene Type, Georgia						
Satilla-Suwannee	21.7(2)	4.9(2)	5.2(2)	40-59	<.06	.04(2)
Pleistocene Type, N.C.						
Natural	7.5-34	--	--	40-200	0.14-0.68(4)	.09(4)
Channelized	5.0-21	--	--	70-260	0.58-1.0(4)	.12(4)

natural levees, old levees, higher terraces (possibly relating to a pluvial period between 18,000-10,000 years ago), residual sandhills (remnants of former Pleistocene shore lines), ox-bow lakes, sloughs and depression pools. These rivers and their adjacent floodplains should be viewed as dynamic features of the landscape, because rivers continually move laterally, erode, and deposit through geologic time.

PHYSICAL-CHEMICAL CHARACTERISTICS OF RIVER SYSTEMS

Properties of Rivers

It is instructive to review the physical-chemical properties of rivers during a typical water year in Georgia (Table 1). We see that mountain streams appear characteristically low in nutrients, conductance, hardness, and total organic carbon (TOC). Eutrophication of Piedmont streams is apparent, with increases of nitrogen, phosphorus, and organic carbon. Alluvial rivers gain more calcium and magnesium and become harder when they reach the Coastal Plain. The Flint in particular crosses the Limesink Region and receives calcium-rich underground flow.

Among the blackwater rivers the Ochlockonee most closely resembles an alluvial stream and carries a good deal of sediment from the Tallahassee Red Hills, a physiographic variant of the Miocene Tifton Plateau. Its hardness suggests that it too receives calcium-rich subterranean flow. Blackwater rivers are typically low in nitrogen and phosphorus. The Ogeechee heads in the Fall Line Red Hills and the clay-base hills of the Tifton Plateau; hence its chemistry somewhat resembles alluvial rivers. Although the Canoochee also heads on the Tifton Plateau it more nearly resembles the typical blackwater rivers with their very soft, very acid and organic-rich water. In the most acid streams such as the Satilla or Suwannee, the ratio of dissolved inorganics to organics is roughly 1:1, whereas the world average for rivers is 10:1. Iron and aluminum, derived from shallow groundwaters, comprise the bulk of inorganics in blackwater streams. Alluvial rivers carry large amounts of inorganics as silts and clays (both types move bed loads of sand) which constitute a "nutrient subsidy" to floodplain vegetation which is thus relieved of "mining" deep soil layers.

Riparian systems with a substantial wetland component export considerably more organic carbon than those with only well-drained uplands (Brinson 1976). Mulholland (in preparation) attributes the high organic exports (2 - 8 gTOC/$m^2 \cdot yr$) and high concentrations of blackwater streams in eastern North Carolina to increased contact times between water and organic debris as well as to the concentration effects of high evapotranspiration in swamps. However, much of the organic matter of blackwater rivers is in dissolved form as humic substances, resembling soil fulvic acids with a small percentage resembling soil humic acids (Reuter and Perdue 1977). Reuter (pers. comm.) estimates that 80% of TOC (Table 1) is probably humic substances and, since these are 50% carbon, multiplying 80% of the TOC by two, yields the amount of humic material in a stream. The Satilla and Suwannee thus carry about 33.6 mg/liter of humic material. These substances give the characteristic "tea color" to blackwater rivers. The pH of Piedmont streams is higher than the strictly Coastal Plain streams because of neutralizing bases which

weather from bedrock and because dissolved organics are too low to color the water. Reuter and Perdue (1977) feel that most humic substances derive from the organics in upland soils, being forced out by rising water tables during storms. Others believe that the decayed detritus and muck soils of innumerable tributaries are adequate sources. For example, Brinson (1977) found that between 10 and 40% of the dissolved organic carbon leached from freshly fallen leaves in a swamp was composed of phenolic compounds.

The extent to which these and other sources of organic carbon are available for microbial assimilation is of great importance and warrants further study. While most of the organic matter may be in the form of refractory humic and fulvic compounds as mentioned above, there still remains a considerable quantity of other organic compounds. These remaining compounds may be more labile and their concentration alone may be as high or higher than the TOC of some mountain and Piedmont rivers (Table 1). Even for the more resistant organic matter fractions that are mineralized slowly by bacteria and fungi (Wetzel 1975), the slowness of the process is somewhat compensated by the long residence time of water on floodplains.

In any event, heavy metals react with humic substances by ion-exchange, adsorption, and chelation, even in the presence of abundant calcium. This implies that heavy metals and pesticides can be removed from food chains and carried out to sea by blackwater rivers. Large fractions of aluminum and iron drop out in estuaries (Kevin Beck, pers. comm.). If indeed the humic substances are flushed from upland agricultural lands, they will carry pesticides and metals into the swamps which will either retain them or flush them on through to the ocean. The catastrophe-resistant tolerance of wetlands can, with care, be exploited by man. However, regarding the oceans as a means of dilution may simply be transferring the problem downstream.

Properties of Floodplains

The sediments of floodplains range from those that are predominately silt and clay to those that have a large amount of organic matter. One of us (Wharton) found the surface soils of Florida's alluvial floodplains to be clay rich but organic poor, averaging 3.9% organic matter, while the upper 6 inches to 3 feet of blackwater and spring run floodplains were black mucks containing an average of 45% organic matter. This does not mean that blackwater floodplains produce more organic matter, but merely demonstrates that its oxidation is inhibited by anaerobic, acid conditions. In contrast to blackwater floodplains, alluvial river floodplains are generally better drained during low discharge rates and have greater water movement on the floodplain when they are flooded. However, poorly drained pools and backswamps of alluvial floodplains, particularly the "water dam" systems, will be high in organic matter, receive low amounts of silt and clay deposits, and may resemble the soils of the blackwater stream floodplains. For some blackwater streams, the floodplain may even be low in organic matter if they are geologically young and are undergoing some downcutting and headward extension.

Floodplain soil surfaces will switch from aerobic to anaerobic conditions, depending on the balance of atmospheric oxygen supply and demand by the sediments. Temporal changes between reducing and oxidizing conditions at the soil surface is one of the most unique attributes of wetlands in general. Reducing conditions favor metabolic pathways such as methanogenesis, sulfate reduction, and denitrification. Ammonium and phosphate will tend to diffuse from the sediments to the overlying water. Under oxidizing conditions decomposition is accelerated, and many of the accumulated products of anaerobic metabolism are oxidized. This has important implications for nitrogen cycling in floodplains. When nitrate is added to surface water in contact with sediments, it disappears (presumably by denitrification) much more rapidly (90% in 10 days) than when ammonium is added (50% in 10 days) (Bradshaw 1977). Ammonium must first be nitrified, i.e., converted to nitrate, before denitrification can occur in the anaerobic sediments.

A diagram of the pathways of nitrogen in a forested wetland is illustrated in figure 1.

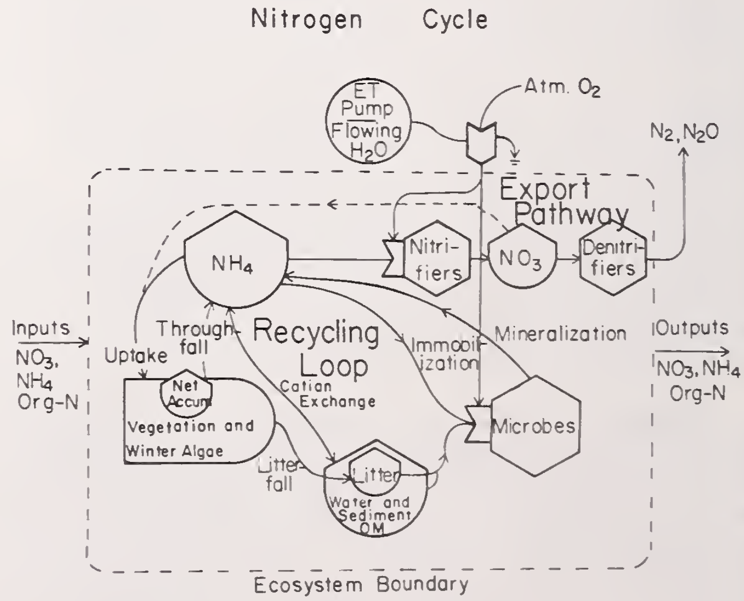

Figure 1.--Pathways and storages of nitrogen in a forested wetland ecosystem. Symbols after Odum (1971).

Storages and pathways of conversion are shown in addition to inputs and outputs across ecosystem boundaries. Conceptually, the cycle can be divided into (1) a recycling loop where ammonium may undergo a number of transformations including uptake by plants, leaching as throughfall, mineralization, immobilization, and cation exchange, and (2) an export pathway where ammonium is nitrified aerobically and the resulting nitrate is denitrified anaerobically. For highly organic sediments or floodplains with a substantial litter layer, the high carbon to nitrogen ratios normally present will result in immobilization of inorganic nitrogen, particularly ammonium, by heterotrophic microorganisms following autumn leaf fall (Brinson 1977). Net mineralization may not occur for several months during which time filamentous algal mats in winter and early spring provide a temporary sink for inorganic nutrients. Uptake by trees is yet another pathway that probably reaches highest rates during the following spring and early summer. The net effect is that these pathways of uptake and exchange in the recycling loop appear to dominate over nitrification and thus result in nitrogen conservation by the system. Although flooded and/or anaerobic soils have been attributed with a high capacity for denitrification based on laboratory experiments (Patrick and Tusneem 1972; Reddy and Patrick 1975; Burford and Bremner 1975), the actual rates that occur in nature may be limited by the supply of nitrate to the export pathway (fig. 1).

Stream channelization, which eliminates the natural contact of floodwaters with the floodplain floor, demonstrates the importance of floodplains in altering water quality. For blackwater streams in North Carolina (Table 1), Kuenzler et al. (1977) report higher levels of nitrate, total phosphorus, and specific conductance in channelized as compared with natural streams. The natural streams contribute more organic carbon to downstream systems.

Blackwater systems with thick peat beds can provide tertiary sewage treatment. In Sumter County, Florida a 506 acre gum-cypress swamp over peat treated the sewage of Wildwood (population 2,500) for 19 years. Flow through the seepage swamps removed 98% phosphorus and 90% nitrogen and reduced fecal coliform bacteria from 16,000,000 to 3,000 per liter in 2 miles of swamp. This swamp was calculated to be worth $79,399 per year in tertiary treatment benefits (Brown, et al. 1974). Radial growth of cypress was much increased.

Alluvial floodplains also act as pollutant sinks but indifferent ways, such as adsorption to clay particles (a major strategy) and utilization in biological food chains. (Pesticides cling to clay and organic particles at levels 10,000 to 100,000 times higher than their concentration in water). Alluvial floodplains have shown to be sinks for radioactive cesium, oil (Wharton 1977); nitrogen and especially phosphorus (Kitchens et al. 1974; Holmes 1977; Wharton and Hopkins in prep.); sewage (Wharton 1970); and fly ash (Guthrie et al. 1974).

BIOTIC COMPONENTS AND PRODUCTIVITY

Primary Producers

Floodplain forests are among the highest in primary productivity of any ecosystem in the southeast (Brown et al. this volume). It has been shown experimentally that alluvial bottomland forest soils are more fertile and support more rapid growth of water tupelo seedlings than the soils of non-alluvial headwater swamps (Harms 1973). Conner and Day (1976) reported that litterfall in bottomland and cypress-tupelo stands in Louisiana exceeded most values reported for warm temperate upland forests. A study by Boyd (1976) showed that laurel oaks (Quercus laurifolia) were both taller and larger on the Oconee's (Georgia) alluvial floodplain than along the non-alluvial Canoochee. Not only does the soil fertility of alluvial swamps depend on water flow for its source of silts and clays, but these currents provide the nutrient supply and aeration necessary for optional growth.

Because of the deciduous habit of most floodplain forests, greatest light penetration to the forest floor coincides with the winter hydroperiod. One of us (Brinson) has observed extensive mats of filamentous algae developing in late winter and early spring and measured dissolved oxygen concentrations ranging from predawn values of less than 1 mg/liter to mid afternoon peaks above saturation. These large fluctuations are not only indicative of high rates of primary productivity when trees are dormant but they also may be responsible for diurnal switching between anaerobic and aerobic conditions at the sediment-water interface.

Primary productivity in southeastern river channels is probably much more limited. Alluvial rivers, as mentioned previously, usually carry heavy loads of silt and clay which restrict light penetration and limit primary production. The upper reaches of the Pamlico River (N.C.) estuary, which receives most of its water from an alluvial river system, is extremely turbid at high discharge. High rates of primary productivity only occur during low flows in the autumn months (Davis et al. 1978). For the clearer blackwater rivers that are large enough that little shading of their channels occurs, much less is known. However, diatoms on sandy bottoms and algae attached to snags are the most apparent primary producers. In general densities of phytoplankton are extremely low.

The metabolism of clear Florida springs is dominated by aquatic macrophyte communities (Odum 1957). On rocky bottoms of Piedmont and mountain streams, the moss-like Podostemon ceratophyllum is a conspicuous primary producer. Except for the Florida springs, litter input and detritus flushed from swamps is probably the most important source of organic carbon for river channels.

The species composition of floodplain forests varies greatly with small changes in elevation. Alluvial floodplains are frequently dominated by a wet-adapted oak-hickory forest. Wetter portions have water hickory (Carya aquatica) and overcup oak (Quercus lyrata), drier sites have sweetgum and water oak. Wet depressions and flowways support bald cypress (Taxodium distichum) and tupelo gum (Nyssa aquatica); the acid backswamps have swamp black gum (Nyssa biflora). Blackwater rivers support pond cypress, swamp black gum and Ogeechee lime (Nyssa ogeechee) over most of the floodplain. Some peninsula Florida bog-type streams with minimal fluctuations have white cedar (Chamaecyparis thyoides). Florida's Yellow River is intermediate, having a beautiful backswamp of cypress, sweet bay, and white cedar.

Consumers

Trees are the floodplain's primary producers and the source of much of the detritus on the floodplain and in the rivers. Food chains on the floodplain floor are detritus-based, some using allochthonous debris from upstream, while others in backswamps are more dependent on autochthonous sources (leaf fall). Floodplains conserve and recycle nutrients in debris by modified versions of upland forest strategy: bacteria colonize leaves and are "grazed" by a host of invertebrates, then nutrients are absorbed by special filamentous algae which, as water levels fall, release them to mycorrhizal fungi on the shallow root-mat of trees. Productivity is high. Holder (1971) found floodplain productivity along the Suwannee to be 15-20 times that of the channel (crayfish at densities of 19/100 m^2 formed over one-third of the floodplain animal biomass).

Much of the particulate organic matter in alluvial stream channels may originate on the floodplain floor. The high weight of detritus in Table 2 for the Altamaha on 9 April was attributed to a 30 cm rise of the river over its floodplain (Wallace et al. 1977). For 16 sample days (4 Feb. - 21 July 1976) a net was used to collect detritus (> 500 µm) in the Altamaha at Baxley, Georgia. The river carried 769 kg/day of dry weight detritus (James Gardner, pers. comm.). However, this amount is only 0.3% of TOC (<500 µm, i.e., colloidal and dissolved), which was transported at a rate of

Table 2.--Spring and fall loads of detritus, vascular plant fragments and diatoms in Altamaha and Tallulah River water. After Wallace et al. (1977).

Date	Detritus No. particles/ℓ	Plant Fragments No. particles/ℓ	Diatoms No./ℓ	Ash free dry wt. mg/ℓ
		Altamaha River		
9 Apr 74	4.8×10^6	7.8×10^3	315,300	4.4
29 Oct 73	3.2×10^6	3.9×10^3	156,100	1.5
		Tallulah River		
19 Apr 75	7.8×10^5	5.1×10^4	447,700	1.2
13 Oct 74	1.3×10^6	7.8×10^3	73,500	0.66

256,697 kg/day). River food chains are based largely on this drifting detritus down to 1 µm in size. Some filter feeders (caddisflies) may utilize diatoms (Table 2) and the larvae of blackflies (Simulium sp.) are even able to capture bacteria (Fredeen 1964). Wallace et al. (1977) found that different species of caddisflies had different net opening sizes in their larval nets so that they could take advantage of the wide size range of detritus and even diatoms. Unfortunately the TOC figures in Table 1 do not differentiate between particulate organic matter available for animals and the dissolved unavailable organic carbon. Particles larger than ca. 500 microns are excluded altogether.

This detrital organic matter supplied to invertebrate life forms the basis for food chains that feed fish, birds, and mammals. Mountain and Piedmont stream diversity is based upon the abundance and size of detritus from the watersheds, and on the variety of habitats provided by a natural stream (Table 3). There are special food chains in floodplain sloughs, backwaters and pools. Underwater snags, logs and debris are extremely important in supporting fish populations in Coastal Plain streams which generally lack stable substrates. The same invertebrate groups (i.e., stoneflies, mayflies and caddisflies) that occur on rocks in mountain streams, also occur on underwater snags in still stretches of Piedmont streams and throughout Coastal Plain rivers. The Satilla, a blackwater stream, has been studied by Arthur Benke (pers. comm.). Densities on snags here are high: blackflies (Simulium sp.) may reach 20,000/m^2. Caddisfly densities range from 4,700 to 10,000, sometimes to 42,000/m^2. Benke also found very high numbers of tiny chironomid midges (> 40,000/m^2) in the sandy bottom of the Satilla. In the Ochlockonee, Edward Hall (pers. comm.) has found as many as 11 species of caddisflies and 20 species of true flies.

Blackwater creek beds and alluvial floodplain pools have faunas that are adapted to annual "drydown". In Piedmont floodplain pools there is a winter-spring cyclic abundance of one organism following another: the sequence is

Table 3.--Macroinvertebrate densities in a Georgia Piedmont stream. Numbers are monthly averages of organisms per m^2. Those with large values are detritus feeders; some (caddisflies) capture particles with nets. Data courtesy of Caldwell (1973 and pers. comm.).

Taxa	Granite shoal	Riffle	Pool
Stoneflies			
Acroneuria	0	968	0
Leuctra	0	2014	0
Isogenus	499	0	0
Mayflies			
Ephemerella	1874	2417	0
Isonychia	944	1841	0
Stenonema	260	5515	0
Baetis	272	1099	0
Hexagenia	0	0	476
Caddisflies			
Cheumatopsyche	218	2359	0
Hydropsyche	5777	8583	0
Rhyacophyla	107	696	0
Flies			
Chironomidae	1346	943	505
Tipula	22	253	0
Beetles			
Anchytarsus	49	885	0

stoneflies, mayflies, amphipod and isopod crustaceans, and oligochaete worms, all keyed to pool drydown and lowering oxygen levels (Parsons and Wharton 1978). Edward Hall (pers. comm.) reports that Coastal Plain blackwater tributary creeks regularly quit flowing and dry down into a series of pools, some of which have algal blooms raising the pH into basic range. Oxygen goes down to critical levels (0.2 - 1 mg/l), yet small fish of quite a few species survive. The benthic insect fauna disappears. The recovery in winter is remarkable. Nelson and Scott (1962) studied a Piedmont shoal (Oconee River), documenting a remarkable and often rapid winter recovery of insect populations and the cold-tolerant Podostemom plant following high water. Insects were washed downstream to become part of the "drift".

Organismal drift is a feature of southern streams from their very headwaters until they reach the lower coastal areas. Gardner and Woodall (1975), using an underwater net in the Altamaha, tallied 115 taxa including stoneflies (12 genera), mayflies (14 genera), caddisflies (19 genera), dragonflies (17 genera), beetles (27 genera), and 10 families of flies. Four groups, mayflies, beetles, waterfleas (Cladocera) and stoneflies, comprised 84% of the drift. In April 1974, the maximum numbers of drift organisms were $6.5/m^3$ by night and $2.2/m^3$ by day. Maximum density followed high water.

LONGITUDINAL AND LATERAL GRADIENTS

The entire length of a river must be considered in evaluating the function of its parts. Table 1 indicates that there are physical-chemical river water gradients (i.e., TOC increases steadily in the Altamaha from headwaters downstream: 1.8, 2.9, 4.1, 7.9 mg/l). Hydrological phenomena are no less important. Livingston et al. (1974, 1975) have documented that north Georgia rainfall is the most important determinant of the productivity of Apalachicola Bay. This bay is the west coast's crab-spawning ground and supplies 80% of the state's oysters. Ninety percent of offshore shrimp and 75% of all commercial fish landings in Franklin County, Florida, depend on Apalachicola Bay as a nursery and feeding ground. Not only does the annual high water regulate the bay's salinity and productivity, but it can now be shown (Livingston 1978) that the bay's cyclic productivity depends not only upon annual pulses of organic matter and silt, but on a major high flow every 6 to 8 years, the origin being northern Georgia. Fresh water influence on the bay is dramatically revealed by enhanced Landsat satellite imagery (Graham et al. 1978). It is surprising to consider that the blue crab catch off the lower Gulf shores of peninsular Florida is dependent upon rainfall in the Georgia mountains! Hence anything modifying water delivery anywhere in the watershed, such as clear-cutting, damming, or channelization, may have profound effects on streams, estuaries, and coastlines hundreds of miles downstream. Fortunately, the Apalachicola is not flow-regulated during the high flows of January through May, but it is during low flows. Flow regulation by dams, dredging for navigation (which increases stream gradient and erosion as in the Savannah River), or diversion of water from one river to another (see Wharton 1977) must be viewed as hazardous to southeastern rivers and estuaries. Many fishes tie their life cycles to these river "pulses", either leaving the channel to feed and spawn on the floodplain or in tributaries. Day et al. (1975) found that a river swamp fed a Louisiana estuary (Barataria Bay, which accounts for 45% of state commercial fish production) with pulses of carbon, nitrogen, and phosphorus at the precise time when migrant species were entering the estuary for growth and spawning.

The Altamaha and tributaries (Ocmulgee-Oconee) provide a good example of longitudinal gradient in its use by anadromous fish (Adams 1970). The American shad (Alosa sapidissima) spawns between river miles 60 and 170 and uses

most of the length of the river as a nursery, with primary centers at miles 21-30 and 100-110. Hickory shad (Alosa mediocris), unlike the other species, spawn in oxbow lakes on the floodplain, and in sloughs and tributaries largely between miles 5-137. Blueback herring (Alosa aestivalis), on the other hand, spawn on the floodplain floor among the bottomland hardwoods, largely between river miles 5-137; their primary nursery lies between miles 10 and 40. Other anadromous fish such as the striped bass (Roccus), the Atlantic sturgeon (Acipenser oxyrhynchus), and the endangered shortnose surgeon (Acipenser brevirostrum) may spawn as far upstream as the edge of the Piedmont. The southern flounder (Paralichthys lethostigma) and striped mullet (Mugil cephalus), predominately marine species, also migrate as far up as river mile 120. Both the hogchoker (Tinectes maculata) and the needlefish (Strongylura marina) are now known to spawn in the mid-reaches of the Altamaha (John Adams pers. comm.). Thus each section of the river is important for one species or another, or contributes uniquely to water flow or chemistry. Equally important is opportunity to migrate laterally on the floodplain as noted for blueback herring above, for catfish and centrarchids (Woodall et al. 1975) on the Altamaha, and for numerous species on the Suwannee studied by Holder (see Wharton 1977). Work by Gasaway (1973) and Hall (1971) have shown the tremendous importance of tributary streams and headwater swamps as spawning, nursery, and restocking areas for replenishing the fish fauna of southern rivers. Movements up tributaries as well as onto the floodplain are timed to coincide with annual high water. Even frogs and crayfish show movement patterns up and down tributary streams. There now is little question about the damage that channelization and swamp drainage do to tributaries and headwater swamps with the subsequent impoverishment of fish fauna in the main channel.

The effect of clearcutting and ditching on the Apalachicola delta, and in the adjacent Tate's Hell area of Florida has severely damaged marine productivity in East Bay, primarily due to intrusion of low-quality, acid runoff following logging and site preparation (Livingston 1978). This acid influx is readily apparent in satellite imagery (Graham et al. 1978).

Rivers supply silt even to salt marshes. Lunz (1938) described a 1936 high flow of the Santee which deposited a layer of silt (up to 25 mm deep) over the Cape Romain marshes 12 miles or more from the river's mouth. During high water and northwest winds, many square miles of ocean shelf near Cedar Key (Levy County, Florida) turn coffee-colored and bear hyacinth rafts from the Suwannee River 14 miles to the north.

CONCLUSIONS

From our brief look at southeastern river ecosystems, we can see that by their handling of large quantities of inorganic and organic matter and by their natural adaptation to annual catastrophism in the form of high water pulses, these stream systems remain not only highly productive but manage water in ways which are currently or potentially of life support value to human populations. The key to the survival of both natural and human riparian interactions is the hydrologic regime. Residence time of water on and off the several floodplain types is critical not only for the biotic food chains but for anti-pollutant functions. The natural clay-rich floodplains in alluvial systems immobilize or consume excessive enrichment and toxicity under natural flow regimes, while blackwater stream floodplains immobilize or convey these substances out of the system by virtue of their organic-rich substrates and humic-laden waters. Animal productivity of floodplain and channel life is geared to utilize precisely dimensioned organic material originating in forest systems that stabilize vulnerable upland and floodplain soils. Human action that dams, dredges, diverts, or deforests riparian systems, especially when interfering with the natural hydrologic regime, will not only alter and reduce natural biotic productivity, but will damage critical capabilities for human life support, including deterioration of coastal zone marine tidal systems.

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The Lower Colorado River: A Western System[1]

R. Roy Johnson[2]

Abstract.--A historic look at the Colorado River will illustrate the drastic effects of human activity on most Western rivers. Engineering features for the management of water and electric power have resulted in increased evaporation, associated salinity, and other physicochemical changes; drastic reduction in many native plant and animal populations; increasing populations of introduced species; and changes in erosional and sedimentation rates.

"On the map the Delta was bisected by the river, but in fact the river was nowhere and everywhere, for he could not decide which of a hundred green lagoons offered the most pleasant and least speedy path to the Gulf. So he traveled them all, and so did we. He divided and rejoined, he twisted and turned, he meandered in awesome jungles, he all but ran in circles, he dallied with lovely groves, he got lost and was glad of it, and so were we." -Aldo Leopold in "A Sand County Almanac." (1949).[3]

"It has withstood man's attacks longer than James Ohio Patie's Hee-lay, (Gila) but in its function and even in its form, it is fast becoming a ditch. Dammed, artifically fed, stripped of its vegetation, its flow regulated, its wildlife depleted, the Verde is not merely tamed and domesticated, it is broken and emasculated - not yet dead but mechanically lifeless, an uncomplaining servant, dutifully obedient to its master." -James W. Byrkit in "A Log of the Verde." (1978).

INTRODUCTION

Riparian habitats in the arid Southwest are widely scattered but highly visible. The ephemeral, intermittent, and permanent streams of this region commonly flow through semiarid to arid terrain whose annual precipitation varies from less than 3 inches to more than 15 inches. Evaporation rates may approach, or even exceed, 100 inches each year. Even when Southwestern streams flow through relatively mesic areas the species of plants which constitute riparian communities usually differ sufficiently from the surrounding uplands to be obvious from a nearby prominence, an airplane or even on a high altitude photo. When compared to the drier surrounding uplands, these riparian wetlands with their lush vegetation are attractive oases to wildlife and humans alike.

In the recent Southwest as well as throughout recorded world history, and even prehistory, man has at least indirectly acknowledged the importance of riverine systems through transportation, settlement, and use patterns. These riverine systems have been widely used for exploratory routes; hunting, fishing and fur trapping; settlements, forts and cattle operations and, finally, extensive agricultural and urban developments. In spite of all this, riparian communities continue to be among the most neglected and poorly understood entities within the vast array of North American ecosystems. Even though the early explorers and settlers knew that they could more easily find plants and animals along streams to provide food, fuel, clothing, and shelter, there was basically no attempt to document and quantify species richness and population densities in these premium riparian habitats until the 1960s (Table 1). In spite of the fact that riparian avifaunas have now been examined for these factors, other vertebrates populations are still poorly understood while riparian invertebrate ecology is essentially unknown.

In the lower Colorado drainage, a general correlation exists between elevation and the dependency of birds on riparian, marsh, and

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[3] From an account of Leopold's visit to the Delta of the Colorado in 1922.

Table 1.--A comparision of breeding bird densities in selected habitats. (After Johnson et al. 1977)

Habitat Type	Locality	Authority	Estimated Pairs/100 Acres nonriparian	riparian
Alpine Tundra				
Spruce-Fir Timberline	Wyoming	Finzel (1964)	15-17	-
Conifer Forest				
Spruce-Alpine Fir	Arizona	Carothers et al. (1973)	170-187	-
Fir, Pine, Aspen	Arizona	Haldeman et al. (1973)	253	-
Pine-Aspen Sagebrush Grassland	Wyoming	Finzel (1964)	18-30	-
Pine	Louisiana & E.Texas	Dickson (1978)	120-146	-
Spruce-Douglas Fir	Arizona	Balda (1967) [6]	380	-
Ponderosa Pine	Arizona	Balda (1967)	336	-
Ponderosa Pine	Arizona	Haldeman et al. (1973)	232	-
Relict Conifer Forest [1]				
Cypress post climax	Arizona	Johnston & Carothers (Ms.)	93	-
Riparian Deciduous Forest				
Mixed Broadleaf	Arizona	Balda (1967)	-	304
Mixed Broadleaf	Arizona	Carothers et al. (1974)	-	332
Cottonwood	Arizona	Carothers & Johnson (1975a)		1059[3]
Cottonwood	Arizona	Ohmart & Stamp (no date)[2]	-	683
Temperate Woodland				
Pinyon-Juniper	Arizona	Hering (1957)	33	-
Pinyon-Juniper	Arizona	Beidleman (1960)	30	-
Encinal (Oak)	Arizona	Balda (1967)	224	-
Subtropical Woodland (Bosque)				
Sonoran Desert Mesquite	Arizona	Gavin and Sowls (1975)	-	476[4]
Chihuahuan Desert Mesquite	New Mexico	King (1976)	-	756
Eastern Temperate Forest				
Pine-Hardwood	Louisiana & E. Texas	Dickson (1978)	143	-
Mature Deciduous	W. Virginia	Audubon F.N. (1948)	362[5]	-
Virgin Spruce	W. Virginia	Audubon F.N. (1948)	381	-
Eastern Bottomland Hardwoods				
Tupelo Swamp	Louisiana & E.Texas	Dickson (1978)	-	592
Oak-Gum	Louisiana & E.Texas	Dickson (1978)	-	301-346
Grassland				
Temperate Grassland	Arizona	Balda (1967)	64	-
Short Grass Prairie	Wyoming	Finzel (1964)	99-115	-
Yucca/Grassland	Arizona	Balda (1967)	31	-
Desert Scrub				
Chihuahuan Creosotebush	New Mexico	Raitt and Maze (1968)	9-18	-
Sonoran Paloverde/Sahuaro	Arizona	Tomoff(1974 & pers.comm.)	105-150	-
Mohave Mesquite Dunes	Nevada	Austin (1970)	6-11	-
Temperate Marshland				
Cattail Marsh	Arizona	Carothers & Johnson (1975b)	-	175-176
Marsh	California-Arizona	Anderson & Ohmart (1976)	-	215-283
Cultivated, Urban & Suburban Lands				
Urban (Artificial riparian)	Arizona	Emlen (1974)	-	615[5]
Cottonwood	Arizona	Carothers & Johnson (1975a)	-	605.2[3]

1 Arizona vegetation types after Brown and Lowe (1974).

2 Ohmart, R.D. and N. Stamp. No date. Final report on the field studies of the nongame birds and small mammals of the proposed Orme Dam site. Bur. of Recl. Proj., Boulder City, Ariz. 54 Ms. p.

3 Riparian cottonwood habitat disturbed by urganization. Two years prior, when the habitat was undisturbed, the density was 1058.8 pairs/100 acres.

4 Average density for April and May, the height of breeding activity in the mesquite bosque.

5 Density given in number of adult birds per 40 hectares (100 acres) instead of males or nesting pairs by Welty (1962) and divided by 2 for this table.

6 Balda, R. P. 1967. Ecological relationships of the breeding birds of the Chiricahua Mountains, Arizona. Ph. D. dissertation, Univ. of Illinois, Champaigne - Urbana.

7 King, H. T. 1976. Bird abundance and habitat in a southern New Mexico bosque. Masters thesis, N. Mex. St. Univ., Los Cruces.

other types of wetlands. Although Southwestern riparian habitats at higher elevations are important, the general rule is that the lower the elevation the larger the percentage of nesting avian species that are partially or entirely dependent on riverine ecosystems (Table 2). Water is apparently the limiting factor which determines this phenomenon.

From the small amount of information available there seems to be a contrast in the level of importance between the riverine riparian habitat of the Southwest and the more mesic habitats to the north and east. Some avian studies in the eastern forests suggest that bottomland hardwoods and/or swamp forests may support a greater avian species richness and population density than the surrounding uplands (Dickson 1978). However, the little avifaunal information available suggests that the magnitude of differences between the eastern riparian wetlands and the adjacent uplands may be almost as great as for southwestern situations in some instances but not in all. Further studies are needed to clarify this issue as well as to provide other important information regarding riparian ecosystems in general.

The objectives of this paper are threefold: (1) to discuss management problems in respect to the importance of arid land riparian habitats to wildlife, recreational and aesthetic

Table 2.--Numbers of avian species regularly breeding in selected areas of the Southwest with percentages of birds based on nesting habitat.

AREAS	WETLANDS (LAKES, MARSHES)	WETLANDS & OBLIGATE RIPARIAN	OBLIGATE RIPARIAN	PREFERENTIAL RIPARIAN	SUBURBAN AND AGRICULTURAL	NON-RIPARIAN	TOTAL SPECIES
Blue Point Cottonwoods [1]	-	10(17%)	16(28%)	17(29%)	1(2%)	14(24%)	58 *
Salt River Valley [2]	-	14(16%)	24(28%)	20(23%)	5(6%)	23(27%)	86
Central Arizona Mountains [3]	-	-	7 (7%)	22(22%)	3(3%)	70(68%)	102
Flagstaff [4]	6(5%)	9 (7%)	8 (6%)	22(18%)	2(2%)	78(62%)	125
Grand Canyon [5]	-	4 (3%)	16(13%)	17(14%)	2(2%)	83(68%)	122
Arizona [6]	8(3%)	23(10%)	41(17%)	52(22%)	6(2%)	112(46%)	242
Southwest Lowlands [7]	4(2%)	31(19%)	43(26%)	43(26%)	6(4%)	39(23%)	166

1. Simpson, J. M. & R. R. Johnson. Ms. History and ecology of the avifauna of Blue Point Cottonwoods, Maricopa County, Arizona.
2. Johnson, R. R., J. M. Simpson and J. R. Werner. Ms. History and ecology of the avifauna of the Salt River Valley, Arizona.
3. Reynolds & Johnson 1964; Johnson, R. R. [1970-72] The effect of chaparral modification on breeding song bird populations in Sycamore Canyon and Brushy Basin, Tonto National Forest, Arizona. Annual Rpts. to Rocky Mt. For. & Range Exp. Stn., Tempe; and R. R. Johnson field notes, Bradshaw Mountains, 1968-1977.
4. Carothers, S. W., R. P. Balda & J. E. Hildebrand. 1970. A checklist of the birds of Flagstaff, Arizona. Mus. of N. Ariz., Flagstaff, 4 p. field checklist.
5. Brown et al. 1978; field notes, NPS files, Grand Canyon National Park.
6. Phillips et al. 1964 and R. R. Johnson field notes.
7. Johnson et al. 1977 and R. R. Johnson field notes.

* 6 additional species have nested at least once, including the Bald Eagle.

values; (2) to review the extent to which past and current land and water management practices were, and are, modifying native riparian ecosystems in the Lower Colorado Basin; and (3) to discuss the maintenance and preservation of "second growth" riparian vegetation which we shall call a "reclamation disclimax." It should be a foregone conclusion that as land managers and scientists we must strive to understand and protect the scanty remnants of native riparian habitats. However, with a few exceptions, there has been little concern for the second growth riparian vegetation that has reinvaded modified drainages. Most of the concern for this new riparian habitat type has been from game management agencies such as the Arizona Game & Fish Department and others interested in the non-native saltcedar, especially as nesting habitat for Mourning (Zenaida macroura) and White-winged Doves (Z. asiatica). We shall further discuss the importance of this riparian type in both the Grand Canyon and Salt River Valley sections of this paper.

The Grand Canyon and the Salt River Valley are the two areas which have been selected to illustrate different effects of human activities on riparian ecosystems in the Lower Colorado drainage. The Colorado River in Grand Canyon is still the most nearly "natural" remaining segment of the mainstream of the Colorado River in the Lower Basin, despite the occurrence of Glen Canyon Dam only 16 miles upstream. By contrast, the Gila-Salt-Verde drainage has been so greatly altered that approximately half of their combined lengths is now dry.

GENERAL CHARACTERISTICS

The Colorado originates in the Front Range of the Rocky Mountains on the west side of the Continental Divide in the vicinity of Rocky Mountain National Park in Grand County, Colorado. Flowing southwesterly for 1,360 miles, the river leaves the United States, entering Mexico where it flows another 80 miles before entering the Gulf of California. Now, after almost a century of management of this drainage system, little water flows into the Gulf through the large, nearly dry delta. Although the Rio Grande, the only other major Southwest river, is longer by almost 400 miles, the Colorado drains approximately 245,000 square miles compared to only 170,000 for the Rio Grande. Major rivers in the Upper Basin include the Green, Gunnison, and San Juan while the Lower Basin is mainly drained by the Little Colorado and Gila. A number of smaller, tertiary rivers, usually a couple of hundred miles long and of great importance locally, are found in both the Upper and Lower Basins. In addition, a group of these tertiary rivers contributes to the drainage of the Gila Basin. The Gila, Salt, Verde, and Agua Fria are of special interest because they have been dammed to form storage reservoirs for irrigation and power production. A map of Arizona's perennial streams has been published by Brown et al. (1978).

Political and management considerations have resulted in the dividing of the Colorado into two regions. A point near Lees Ferry, 687.2 miles upstream from the international boundary with Mexico marks the division between the Upper Basin and the Lower Basin. The Upper Basin includes approximately 110,000 square miles of Wyoming, Utah, Colorado, and New Mexico while the Lower Basin drains approximately 135,000 square miles in Utah, Arizona, and New Mexico. In addition portions of California and Nevada are included in the Lower Basin but no major rivers flow into the Colorado River from those states.

Several natural areas along the Colorado and its tributaries are important enough to have been set aside by the National Park Service. In the Upper Basin, these include the aforementioned Rocky Mountain National Park as well as Arches National Park, Capital Reef National Park, Canyonlands National Park, Natural Bridges National Monument, and Dinosaur National Monument. Approximately two dozen National Forests are found throughout the Colorado River Basin. "Preserves" located along the Colorado and its tributaries include the Cibola, Havasu, and Imperial National Wildlife Refuges which are administrated by the United States Fish and Wildlife Service. Indian reservations range in size from the Navajo Reservation, the largest southwestern Indian Nation, (more than 20,000 square miles) to the Yuma and Gila Bend Indian Reservations of only a few square miles each. With the formation of large storage reservoirs along the river system, recreational areas have been established under the jurisdiction of the National Park Service. In the Upper Basin these include Flaming Gorge National Recreation Area on the Green River and Glen Canyon National Recreation Area on the Colorado, while Lake Mead National Recreation Area has been established on the Colorado in the Lower Basin.

In addition to natural areas, e.g. Grand Canyon National Park and Zion National Park, many areas have been set aside because of their archeological importance. Prehistoric Indians commonly settled along streams, sometimes building fortified sites on cliffs and promontories while farming in the nearby floodplains. These national monuments include Gila Cliff Dwellings in New Mexico; and Tuzigoot, Montezuma Castle and Well, Tonto Cliff Dwellings and others in Arizona.

A variety of vegetation types and biotic areas occur between the Colorado's headwaters and its mouth as it flows from glaciated elevations in excess of 14,000 feet at the top of the Rocky Mountains, southwest across the Colorado Plateau, then south through arid deserts to the Gulf of Lower California. In addition, elevations within the Basin descend to almost 250 feet below sea level at the Salton Sea.

Riparian and upland vegetation types along the river and adjacent areas include all of the major formations listed by Brown & Lowe (1974): Tundra, Forest, Woodland, Scrubland, Grassland, Desertscrub, and Marshland. The woody vegetation along the Colorado River bottom varies from willows (*Salix* spp.) and alders (*Alnus* spp.) at higher elevations through cottonwoods (*Populus* spp.), willows and saltcedar (*Tamarix chinensis*) at intermediate elevations to (*Baccharis*), arrow-weed (*Pluchea sericea*), saltcedar, mesquite (*Prosopis* spp.) and cottonwood-willows at lower elevations.

A recent map published by Brown et al. (1978) includes these types: Rocky Mountain, Great Basin, Mohave, and Sonoran Desert. Riparian vegetation includes Rocky Mountain Alpine Scrub, mostly dwarf willows; Rocky Mountain Deciduous Scrub, Willow-Alder Series; Southwestern (Riparian) Deciduous Forest and Woodland, Cottonwood Willow Series and Mixed Broadleaf Series; Interior Southwestern Riparian Scrub, Broom and Seep-Willow Series (*Baccharis* spp.) and Saltcedar Series; Sonoran Riparian Deciduous woodland, Mesquite Series; and Sonoran Riparian Scrub, Mixed Scrub Series, Arrow-weed Series, and Saltcedar Series.

To determine the flora and fauna occurring along various segments of the Colorado River, one must consult the various state and local publications regarding these subjects. In addition, floral and faunal lists have been compiled by many of the aforementioned parks, forests, etc. The riparian vegetation of the Grand Canyon has been mapped by researchers at the Museum of Northern Arizona (Phillips and Phillips unpubl.) and portions of the Lower Colorado by Anderson and Ohmart (Bur. of Reclam., Boulder City, Nev.).

THE COLORADO RIVER IN GRAND CANYON

The Colorado ranks as a third class river, at best, when comparing the natural attributes of great rivers of the world. However, the best known natural feature of the Colorado River drainage, the Grand Canyon, is considered one of the natural wonders of the world. This spectacular canyon is 277 miles long, 13 miles at its widest and more than 1 mile deep at its deepest. The Precambrian schist and granite at its bottom, at 3 billion years of age (Breed and Roat 1976), are among the oldest known rocks on earth. The Grand Canyon has been shown by recent international surveys to be the most popular natural tourist attraction in the United States (various new reports). Hunt (1967) when discussing the geology of the Colorado Plateau mentions Grand Canyon and the Painted Desert as features which contribute to this region as being "easily the most colorful part of the United States."

Although the Colorado was discovered by Hernando de Alarcon in 1540, it was not until 1869 that the 277 mile segment flowing through the Grand Canyon was explored (Powell 1875). One of the better recent anthologies regarding the Grand Canyon is by Babbitt (1978). Although geological interest in this region developed early, it was not until the close of the century that any notable biological exploration was conducted. It was then that Merriam (1890) developed his noted Life Zone concept during investigations conducted from the top of the San Francisco Peaks (12,670 feet) to the bottom of the Grand Canyon (less than 3,000 feet elevation). All of Merriam's Life Zones, from Arctic-Alpine through Lower Sonoran, are well represented along the Colorado River. In addition to the aforementioned information regarding vegetation mapping of the Grand Canyon, Carothers and Aitchison (1976) compiled a floral and faunal list for the riparian zone along the Colorado River in Grand Canyon.

Although Grand Canyon National Park was established in 1919, a thorough inventory of the vertebrates of the region has not been undertaken until recently. The fishes of the Colorado River within the park include 15 introduced and 4 native species (Minckley and Blinn 1976; Suttkus et al. 1976). Tomko (1975) published a list of the amphibians and reptiles and Brown et al. (1978) have just published an annotated checklist of the birds of the region. Hoffmeister (1971) published a book on the mammals and supplemental information has been published by Ruffner et al. (1978) and Suttkus et al. (1978). In addition, field checklists of the terrestrial vertebrates are available from the Natural History Association at Grand Canyon.

New Riparian Habitat "Reclamation Disclimax"

The major reason for our interest in the Colorado River in Grand Canyon is to examine the factors related to newly established riparian habitat. The completion of Glen Canyon Dam in 1963 resulted in environmental changes which were devastating to several

fishes listed as threatened or endangered by the U.S. Fish and Wildlife Service (1973 and supplements published periodically in the Federal Register). Notable examples are the chubs (Gila spp., see Suttkus and Clemmer 1977). On the other hand, some of the post-dam changes in water regimes have been conducive to the establishment of riparian scrub composed mainly of sandbar willow (Salix exigua), saltcedar, arrow-weed and seep-willows. In the rest of the Lower Colorado Basin, there has been a drastic reduction in the total amount of riparian habitat. Further, the little remaining habitat is generally in poor condition due to several factors including: (1) reduction in surface and groundwater; (2) grazing and consequent lack of regeneration; (3) invasion by non-native species, e.g. saltcedar. Ffolliott and Thorud (1974) estimated that less than 1/2 of 1% of the total habitat in Arizona was riparian. Thus, the establishment of riparian habitat in the Grand Canyon is of major interest (Carothers et al., in press).

With the increase in riparian vegetation there has been a (re)invasion by several avian species, such as Bell's Vireo (Vireo bellii), Hooded Oriole (Icterus cucullatus), and Summer Tanager (Piranga rubra) (Brown et al. 1978) as well as an apparent increase in population densities for species such as Lucy's Warbler (Vermivora luciae), Yellow Warbler (Dendroica petechia) and Common Yellowthroat (Geothlypis trichas). It is difficult to determine the magnitude of these changes since no pre-dam surveys of the area were conducted. Factors leading to these changes include: (1) reduction in flood levels from up to 300,000 cfs. (Dolan et al. 1974) before construction of the dam to post-dam maximum flows of between 30,000 and 50,000 cfs, and; (2) a more constant water supply. Pre-dam photos (NPS files) show that vegetation was scoured from the river's banks by these periodic floods. The Colorado now acts like a tidal river with daily fluctuations in water levels determined by water releases related to power generation at Glen Canyon Dam.

The daily tidal fluctuations of the river through providing a more constant source of water for the establishment of riparian vegetation on the terraces ("beaches") at the river's edge, have proven to be a mixed blessing. When coupled with the erosional force of the low silt bearing water which now flows through Grand Canyon, the result is a reduction in size of many of these terraces which bear riparian vegetation (Dolan et al. 1977). In addition, plans for the modification of Glen Canyon Dam to allow releases well in excess of 50,000 cfs (up to 100,000 cfs?) are currently being considered by the Bureau of Reclamation (pers. comm.). Thus, the fate of this newly established riparian habitat is questionable.

WATER STORAGE AND THE SALT RIVER VALLEY

Although the Colorado River is not one of the major rivers of the world, it and its tributaries have been important to humans for thousands of years. This has not changed with modern technology, and, in fact, is now even more important. Construction of gigantic irrigation and power projects have converted almost all rivers in the Lower Basin into a series of reservoirs behind dams, alternating with controlled flows (regulated water released from dams) and dry river beds. Perhaps no river in the United States has been more highly used and modified. Several hundred engineering structures have modified the Upper Basin rivers while more than a dozen large dams have been built on the rivers of the Lower Basin. In addition to storage and diversion dams for power and irrigation, other engineering features include tunnels, dikes and levees, riprapped banks, canals, pipelines, pumping plants, substations, and transmission lines.

Early Irrigation

A discussion of the Verde-Salt-Gila River system will illustrate the extent to which rivers in this region have been modified. This extensive system formerly consisted of three naturally perennial streams and several permanent tributaries which drained central and southern Arizona, and central western New Mexico. Today, less than half of the more than 1,000 miles of river are not impeded by major dams. Even along this half are located diversion structures for local irrigation projects, mining and other uses. The remaining half of the system consists of dry stream bed and more than 100 miles of storage reservoirs and large diversion structures. Most of the water storage programs are conducted by the Salt River Project to provide power and water for Phoenix and the rest of the Salt River Valley.

An examination of the history and prehistory of the Salt River Valley, thus, provides an excellent case study of agricultural and rural development in a river valley. This valley knew continous and successful habitation from at least 200 years B.C. through 1400 A.D. The Hohokam, considered by authorities to be ancestors of the Pimas and/or Papagos, irrigated and farmed the valley, leading what Haury (1967) called a "peaceful and prosperous life." Using stone axes and hoes, they diverted the water of the Salt and Gila Rivers into their corn and cotton fields. It has been estimated that during that time the valley supported a larger rural population than it does today, with small family units and villages situated along the many canals (Haury 1967). Most of today's inhabitants of the Salt River Valley live in Phoenix and its suburbs.

Historically, agricultural development was reintroduced when Jack Swilling began the Swilling Irrigation Canal Company in 1867. His inspiration rested on the understanding that the ancient earthworks in the area had once served the vanished Indian communities. Thus, after 500 years of inactivity, water was once again diverted from the Salt River and flowed through earthen ditches. The irrigation project developed quickly, growing from 100 people and 250 acres in the fall of 1868 to 8,000 acres in 1872. Crops consisted of oranges, grapes, figs, and walnuts. In addition, wheat and alfalfa were grown largely to feed cavalary animals at Ft. McDowell on the Verde River near its confluence with the Salt River just east of Phoenix (Salt River Project 1970). By 1888 a half dozen major canals served the Salt River Valley (Salt River Project, no date a) and by 1982, 107,118 acres were under irrigation (Arizona Republic May 18, 1969).

Reclamation and The Salt River Project

With the expansion of population and the growth of human related activities in the valley, it became inevitable that the possibility of water storage be investigated. Valley farmers, in response to seasonal and yearly variations in weather which they called "drought" were constantly demanding more water. Uneven water distribution, conflicts of interest and legal wrangling over water rights complicated the issues. In 1889, Senator W. M. Stewart of Nevada visited western states to discuss dam sites with local citizens. The Maricopa Board of Supervisors investigated various sites and provisionally selected the Tonto Basin, at the confluence of Tonto Creek with the Salt River. The money for dam construction had to wait for President Theodore Roosevelt's signing of the National Reclamation Act in 1902. The estimated cost was $2,700,000. Costs spiraled and by 1917 the amount was figured at $10,166,000, increasing the cost to shareholders from the original $15 an acre to $60 an acre (Salt River Project, no date a). This loan was repaid in October 1955. The finished dam was dedicated in March of 1911 by President Roosevelt. It was the world's highest masonary dam, having a storage capacity of 1,381,580 acre feet of water (Salt River Project, no date b). From a beginning population of 100 Anglo settlers in 1868, the Salt River Valley has grown to a complex urban, suburban, and rural development. Today, metropolitan Phoenix has a population of approximately 690,000 people with approximately 1,000,000 people residing in the Salt River Valley. To provide water and power for an ever growing population, waters were diverted from the Salt and Verde River systems finally resulting in the Salt becoming dry from Granite Reef diversion dam downstream to its confluence with the Gila. The Verde River has continued to flow to its confluence with the Salt below Horseshoe and Bartlett Dams except when this flow is turned off at Bartlett Dam. In addition, the Gila was "turned off" by the completion of Coolidge Dam (San Carlos Lake) in 1929 and is dry from that dam downstream to its confluence with the Salt and from there west to the Colorado (Dobyns 1978).

Effects of Irrigation on Birds

As was mentioned previously, the lack of early biological records make it difficult to determine the rates and magnitude of ecological changes which accompanied these drastic modifications of the stream systems. Most of our discussions regarding these changes will center on the avifauna. In monitoring the "biological health" of an area we find birds to be a better "thermometer" than other terrestrial vertebrates for several reasons. The first reason is practicality. Most birds are relatively easy to find and observe because they are diurnal and fly. In addition, they sing during the breeding season, allowing one to estimate population numbers. Contrast these characteristics with other non-aquatic vertebrates such as most reptiles and mammals which are nocturnal and/or spend much of their time hidden from view. In addition, disturbed areas which are recovering from ecological damage are more rapidly recolonized by these winged vertebrates than by other terrestrial species. We know of no definitive publication concerning the ecological changes which occurred during the first century of irrigation in the Salt River Valley. Some of the qualitative changes have been discussed orally by Johnson (1972). Thus, we can only piece together information from scattered sources such as from a 1907 egg collecting expedition by oologists. (Hanranft 1908) reports collecting eggs of several species from cottonwood trees in irrigated areas west of Phoenix along the Agua Fria River. Included in the collection were eggs of the Vermillion Flycatcher (*Pyrocephalus rubinus*) and Baird's (Ladder-backed) Woodpecked (*Dendrocopos scalaris*). In Phoenix and vicinity today, both these species are found in small numbers in riparian habitat. The closest nesting Vermillion Flycatchers occur in very limited numbers along the Salt and Verde Rivers, approximately 50 miles east of where these early collectors worked.

During this century several basic changes have occurred in the avifauna of this area. As the rivers became increasingly dry, riparian and aquatic plants and animals diminished in number and distribution along the river courses. However, much of the surrounding desert was replaced with relatively primitive irrigation systems consisting of fields and tree lined

earthen ditches. These ditches simulated small streams and provided habitat for many species of fish, amphibians and other wetland species of animals as well as plants. The trees, shrubs and accompanying vegetation along the ditches provided man-created riparian habitat for 20 to 30 species of nesting birds while pasture and field crops provided nesting sites for several additional species. Small diversified farms which combined the raising of livestock and poultry with a variety of crops resulted in the maintenance of a diverse biota of native species.

With the loss of the native cottonwood-willow forests and mesquite bosques along the Salt and Gila during the first part of the century, many riparian nesting species could not adapt to the new, arid conditions. These included the Ferruginous Owl (Glaucidium brasilianum), Yellow-billed Cuckoo (Coccyzus americanus), Summer Tanager (Piranga rubra) and many others. Some species such as the Gila Woodpecker (Melanerpes uropygialis), Black Phoebe (Sayornis nigricans) and Crested Flycatcher (Myiarchus tyrannulus) adapted well to this new "artificial" riparian habitat around farms and ditches.

In the mid-1900s farming methods changed drastically. Trees were cut down and ditches cemented to reduce water losses from evapotranspiration and percolation. Waste areas along ditches and fence rows which provided food and cover for wildlife were eliminated to produce more acres of cotton and alfalfa. "Clean farming" methods consisted of mass use of herbicides and insecticides. Books, scientific papers, articles, and television shows have widely discussed the direct effects of farm chemicals on wildlife; the indirect effects of loss of food and cover have also been devastating. In one locality near Peoria seven species had ceased to breed by the late 1950s and early 1960s while only three new species had started to nest in the area. The three new species are the Curve-billed Thrasher (Toxostoma curvirostre), the Common Starling (Sturnus vulgaris) (a European introduction) and the Great-tailed Grackle (Quiscalus mexicanus), which has recently extended its range northward from Mexico (Phillips et al. 1964). The last two are closely associated with human activity.

It is difficult to determine which factor or combination of factors has been critical in the loss of any given species in part of its range. In the Salt River Valley, the reduction in populations of many avian species and the complete loss of others has resulted from any one of several different factors or a combination of these factors. These include: loss or disruption of native riparian habitat, cementing of canals and ditches, destruction of trees and other plants along canals and ditches, "clean farming" practices and loss of fence rows and "waste" areas, widespread use of insecticides and other agricultural chemicals and, finally, urbanization.

BIOLOGICAL INVESTIGATIONS IN RIPARIAN HABITAT

Despite the acknowledged importance of river systems to prehistoric, early historic and technologic man, our knowledge of the biological composition of riparian ecosystems, when European man settled the United States is basically non-existent. Early explorers were usually laymen, army officers or scientists (e.g. geologists) who had only scant knowledge of the biota and left poor to incomplete biological records. Even when biologists accompanied exploration parties, they could not even record all of the descriptive information they observed. They often encountered plants and animals which were either poorly known or unknown, such as the Abert's Towhee (Pipilo aberti) which was not known to science until 1852 (AOU 1957), or even more obscure animals such as the humpback chub (Gila cypha) which would not be described until later in the 20th Century (Miller 1946). Early records from rivers such as the Colorado (Emory 1848), and the Gila commonly mention wildlife and vegetation only in general terms. Therefore, when attempts are made to reconstruct the riparian conditions of a river even as relatively well known as the Colorado (Ohmart et al. 1977) a great amount of extrapolation is necessary. Thus, only partial lists of riparian tree species for the Lower Colorado Drainage and to a lesser degree, shrubs, can sometimes be reconstructed from notes left by these biologists during the late 1800s and early 1900s. The prevalent upland game species, waterfowl, furbearers and predators, as well as other general faunal components, were sometimes enumerated. However, herbaceous plants, small vertebrates, nongame wildlife, and invertebrates (other than mosquitoes) were seldom discussed. Information regarding population densities and other quantitative data was not even mentioned.

Ecotones, Edge Effect and Ecological Diversity

The edge effect increases the complexity of the study of riparian habitats. This concept has been only recently developed for it was not until the mid-1900s that the implications of this phenomena were well enough understood to be discussed by ecology texts (see Johnson et al. 1977). Odum (1959) defines the edge effect as "the tendency for increased variety and density at community junctions." One of the first ecologists to deal with the edge effect was Aldo Leopold (1933). He defined the term and emphasized that all of the reasons for the phenomenon were not understood. It is interesting that in

a recent paper on the edge effect Thomas et al. (1978) quoted from Leopold's work but inserted the word "wildlife" to illustrate that these principles apply to wildlife in general and not just game animals. In an earlier publication Carothers and Johnson (1975a) discussed the confusion of the term game management with wildlife management. Some resource management agencies continue to promote game management under the guise of general wildlife management.

Thomas et al. (1978) list two basic types of edges, inherent, and induced. Inherent edges are due to long-term factors such as soil or exposure while induced edges result from short-term factors such as fire or flooding. An inherent edge may be either abrupt or a mosaic. An abrupt edge occurs where environmental conditions result in a relatively sharp junction between two basic habitat types. A mosaic edge has more total edge area than the abrupt type and thus should display a greater total diversity.

Others have noted the increased species richness associated with riparian ecosystems. In California, Miller (1951) although not pointing out the edge effect, stated "the number of species of birds associated with riparian woodland is larger than that of any other formation." Other papers in this symposium document the fact that these California riparian ecosystems have also experienced drastic reductions in wildlife, recreational and aesthetic values.

Another factor related to the edge effect which increases the ecological diversity, and therefore complexity, of these ecosystems is the allied concept of ecotones. Riparian habitats may be considered ecotones between the aquatic habitat of the stream itself and the surrounding terrestrial habitats. As such, the riparian ecosystem contains elements of both the aquatic and terrestrial ecosystems plus retaining unique characteristics not found in those two ecosystems. Care must be taken when dealing with ecotones and the edge effect. Arnold (1972) suggested that removing trees from dense riparian groves would produce clearings which should improve wildlife habitat values. Conversely, Carothers and Johnson (1975a) found that reduction in the number of mature cottonwoods in riparian groves in the Verde Valley of central Arizona resulted in nearly a straight line relationship to reduction in avian populations.

MANIPULATION OF RIPARIAN VEGETATION AND ITS EFFECTS ON AVIAN POPULATIONS

Even in ornithology, the best known of riparian studies, one is fortunate to find a complete list of avian species for either extant or extirpated stream systems. The extremely high densities of riparian avian populations in general was not recognized until this decade (Carothers et al, 1974, Carothers and Johnson 1975b, Hubbard 1977, Johnson and Jones 1977, Johnson 1970, Sands 1977, and Table 1). Although most of the references in this section refer to breeding birds similar findings pertain to transients. Rappole and Warner (1976) found that migrating birds showed a decided preference for riparian habitat and expressed the same concern for these birds that are commonly expressed for breeding and wintering birds. Stevens et al. (1977) found that censuses in riparian habitat commonly resulted in several times the number of migrants when compared to adjacent upland habitat. Thus, destruction of large tracts of choice riparian habitat may effectively interrupt migratory routes and cause excessive losses to migrating species which could have the same deleterious effects as destruction of nesting habitat.

In 1956 a landmark report discussed the possibilities of increased water yield by vegetation management on Southwestern watersheds. This report, commonly called the "Barr Report" (Barr 1956), was at least partially instrumental in establishing programs that were to be carried on into the 1970s. Juniper, brush and other vegetation control projects were often promoted as multiple use projects by government agencies and private "water salvage" organizations. The value of the techniques in restoring range for cattle and wildlife was widely advertised but the underlying cause was always increased water yield.

A more recent report (Ffolliott & Thorud 1974) estimated possible increases in water yields under various levels of vegetation removal in Arizona. This report was not as widely accepted as Barr's since recent benefit-cost studies have demonstrated the financial infeasibility of many of the programs intended to increase water yields. Clary et al. (1974), for example, found that removal of southwestern pinyon-juniper was not likely to increase water yield, and value to cattle and game was questionable since only the more successful conversion projects just about break even from a benefit-cost standpoint.

Some non-riparian brush control projects may improve range habitat for birds (Carothers and Johnson 1975a). However, all management programs which alter riverine ecosystems that we have examined have been detrimental to avian populations with the single exception of the newly created reclamation disclimax in Grand Canyon, discussed earlier in this paper.

Detrimental projects include channelization (Carother & Johnson 1975b), phreatophyte control (Johnson 1970) and water storage projects which inundate riparian areas.

During the 1960s and early 1970s, several agencies were concerned with the loss of water through evapotransporation from phreatophytes. A special interagency organization, the Pacific Southwest Interagency Committee, was organized to examine methods of reducing these reported water losses. In 1966, a PSIAC symposium was conducted to discuss the general problem. One of the most commonly advocated methods, of course, was the removal of vegetation from stream courses. Some of the earlier projects concentrated on the removal of the non-native saltcedar. This soon led to the removal of native riparian species such as cottonwoods and willows.

In 1968 the Arizona State Water Resources Committee sponsored a symposium regarding phreatophyte clearing projects. Bristow presented one of the first papers to address the loss of wildlife habitat in these removal programs. Phreatophyte concerns were so extensive that Horton, a specialist on the systematics of saltcedar as well as various other phreatophyte subjects, compiled a bibliography covering the mass of literature which had accumulated (1973). However, sentiments supporting the philosophy of complete removal of phreatophytes was gradually changing and a year later Horton and Campbell (1974) published a paper on the multiple use values of phreatophytes which addressed, among other subjects, wildlife values. During the four ensuing years, the term "phreatophyte," with its unsavory connotation as a water waster, has become far less frequently used.

UNSOLVED PROBLEMS

A variety of unsolved problems continue to plague us. A few of these are briefly discussed here.

1. Over-allocation and unequitable distribution of water.-In Arizona 89% of water usage is for agriculture, leaving the remaining 11% for all other uses (Arizona Water Comm. 1977). Parenthetically, .8% is allocated to fish and wildlife. Figures for the rest of the arid west are similar. Demands for water so far exceed the supply that a total of 16.5 million acre feet annually have been allocated from the Colorado River despite annual flows averaging less than 14 million acre feet annually between 1922 and 1966 (Dracup 1977).

2. Erosional and other problems created by poorly conceived and designed diversion and irrigation structures.-Current resource management problems often stem from water control structures and use patterns. I shall relate three examples. The first is by Dobyns (1978) who wrote, "About 1883, farmers near Solomonville, irked when San Simon Creek freshets deposited sand, gravel, and other debris on their fields, dug ditches to divert creek waters past their fields. The creek promptly began to erode downward and headward, so that within a few years, a sixty-mile-long channel from ten to thirty feet deep gaped from 600 to 800 feet wide in the San Simon Valley, previously famous for artesian wells. Water dropped, in obedience to the law of gravity, below the floor of the new canyon."

In addressing this same basic problem Brandt (1951) had this to say; "The slender Santa Cruz River, at the point where it flows into the grand mesquite forest, evidently enters a wide level area. Meanwhile it seems to spread its intestine waters out underground in a deltalike fashion, which, due to an impervious substratum, seem to form a sort of subterranean sandy swamp with no water on the surface, but with apparently a broad, rich reservoir not too far below. In May, the river, as it formerly flowed through the forest, appeared and disappeared several times in its sandy bed and was often many channeled. This peculiar combination of natural conditions caused a sweet water level within reach of the long mesquite roots and, while the surface of the ground might have been perfectly dry, it evidently was well watered below, thus giving grateful nurture to the marvelous trees that were fostered there.

About 50 years ago, however, mankind with his destructive 'improvements' appeared. A prominent pioneer named Sam Hughes is said to have constructed the first irrigation ditch at the edge of Tucson. Floods quickly enlarged and deepened this ditch in to a minature gorge, cutting back in a few seasons to an artificial lake at the upper end of town. This deepened channel soon drained the lake and kept on eating its way back towards the forest. Flood waters seem to have extended the gorge with ever increasing speed and were helped in their destruction by other foolish irrigation ventures on up the valley until it reached the forest. The lowered drainage soon caused the sweet water level to drop many feet and when the moisture binder is taken from adobe desert soil the latter becomes finely powdered silt, which can resist but little the savage erosion of the torrential rains that only too frequently occur in that region. A deep channel, consequently, was cut out of the river bottom in the forest, leaving vertical silt bluffs in many places 20 to 40 feet high. Soon lateral grooved canyons developed until at the present day, the river bottom is a master canyon with numerous, hideous cleft

affluents that are gnawing back into the forest and rapidly eating out its green heart. Aside from unwise irrigation ventures, the clearing of the bottom land of the larger tree growth south of the grand mesquite forest, which is up the valley, has been one of the main factors in contributing to the destructive erosion. The reason is that the primitive dense vegetation cover there held back the floods and gave time for much of the water to soak into the soil, permitting the rest to flow slowly down the valley."

Although Brandt was not a hydrologist or erosion specialist, his writing leads one to question the premise that vegetation removal ipso facto is effective in reducing flooding. Cooke and Reeves (1976), in addition to referring to the Santa Cruz Plains, state that, "It seems reasonable to conclude at present that the best hypothesis to explain arroyo formation along the major valley floors of southern Arizona acknowledges the possibility of increased valley-floor discharge due to climatic and/or vegetation changes but emphasizes the role of drainage concentration features and related changes along valley floors."

3. Excessive withdrawal of groundwater.-As early as 1936, Smith pointed out the dangers of lowering water tables, increasing the lift and consequently the costs of pumping water. In 1975 the Arizona Water Commission reported excessive annual withdrawals ranging from 1.8 feet for the Salt River Valley to 13.8 feet for the Harquahala Valley. In addition to eventually running out of water, recent land subsidence due to this excessive withdrawal has resulted in property damage and reduced land values.

4. Problems associated with storage projects. -Of particular concern are water losses from evaporation, and percolation into the bed of the reservoir, as well as increasing salinity. A desalting plant on the Colorado near Yuma will cost an estimated $200,000,000 to construct while operation is estimated at a cost in excess of $16,000,000 annually (USDI-BR 1977).

5. Grazing.-Problems such as a lack of regeneration of riparian vegetation and destruction to the understory are discussed in detail by other papers in this symposium.

6. Loss of native riparian habitat and invasion by non-natives.-Less than 1/2 of 1% of the land in Arizona bears riparian habitat. In Missouri, Korte and Fredrickson (1977) report that when European settlers arrived in the 1700's they found 2.4 million acres of lowland ("riparian") forest. The 98,000 acres remaining today constitute only 4.1% of the original acreage. Similar situations exist in much of the rest of the United States. Turner (1974) presented evidence that non-native "saltcedar can eliminate native riparian species such as cottonwood and seepwillow."

7. Extirpation or reduction in numbers of native animals.-The Endangered Species Act of 1973 deals with species in danger of extirpation. The most notable example of such a species on the lower Colorado is the Yuma Clapper Rail (Ohmart & Smith 1973). A more insidious problem exists in regard to the large percentage of species which are totally or partially dependent on riparian habitat during part or all of their life cycles (Table 2 and Johnson et al. 1977).

8. Problems inherent in manipulation of riverine environments and construction in flood plains.-Our greatest problems stem from settlement activities in floodplains. A subject of increasing concern is floodplain management (Kusler 1976) as loss of life and property in floodplains continue to mount. Rather than solving the problem, expensive flood control projects commonly merely move the problem downstream by channeling water downstream from one location to another. The only suitable answer to this problem is sound land use planning and floodplain management.

SUMMARY

Laws and policies designed to protect riparian values are still sadly inadequate. Cultural artifacts on public land have been protected since 1906 by the Antiquities Act (Lee 1970). Sixty-three years had passed before enough concern was generated to pass the National Environmental Policy Act of 1969, designed to protect the human environment, especially with regard to clean air and water. Four years later the Endangered Species Act of 1973 was passed in an attempt to prevent an ever-increasing number of species from going the way of the Passenger Pigeon and Carolina Parakeet.

As improved techniques facilitate the gathering of scientific information about riparian habitats and their complex and diverse ecosystems several facts become evident:

1. Most human activities along rivers have been detrimental to riparian ecosystems.

2. Better assessments are needed to fully determine the wildlife, recreational, and aesthetic values of these areas.

3. Riparian vegetation is more important than formerly realized in maintaining water quality, probably in the maintenance of clean air and possibly in affecting local climatic conditions.

4. In many, if not most, regions riparian habitats have been reduced to less than 10% of their original areas. Continued reduction of this critical water resource may shortly result in irreversible damage to its human as well as non-human values.

The importance of additional research and improved management in riparian habitats is unquestionable. However, even though better assessments of the values of these areas are needed an informative body of information is currently available. Thus, the greatest task ahead is the wise use of this information to formulate laws and policies for protecting and improving riparian habitats. This action is crucial in contributing to improving our quality of life today and in the future.

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Riparian Ecosystems: Conservation of Their Unique Characteristics[1]

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Abstract.--Riparian ecosystems have two essential characteristics: laterally flowing water that rises and falls at least once within a growing season; and a high degree of connectedness with other ecosystems. Other pulses such as fire and hurricanes may also be important in ecosystem maintenance. Changes in hydroperiod or amplitude of water level fluctuation produce the most dramatic changes in riparian communities. Changes in neighboring ecosystems, which have high rates of exchange of energy and nutrients with riparian ecosystems, may also have significant effects.

INTRODUCTION

Riparian ecosystems occur in both fresh and salt water; not all have distinct channels; and dominant vegetation may vary from low, herbaceous growth to tall trees with high basal area (Table 1). Is there, then, a set of unique characteristics that justifies regarding riparian wetlands as a distinct class of ecosystems? This paper identifies two such characteristics and discusses the effects of human-induced perturbations on the stability of riparian ecosystems.

Table 1.--Examples of Riparian Ecosystems

	Fresh Water	Salt Water
Forested	River swamps Bottomland hardwoods Cypress strands Bosques	Riverine mangroves
Nonforested	Some marshes Some peatlands	Tidal marshes

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PULSES IN RIPARIAN ECOSYSTEMS

One characteristic that distinguishes riparian ecosystems from other wetland ecosystems is the lateral movement of water through the ecosystem together with water level fluctuation, comprising a significant pulse in the physical environment. This pulse may occur daily in coastal ecosystems, annually in temperate or seasonal ecosystems, or irregularly within a year. Perhaps the most important feature is that both high and low extremes occur within a single growing season. A riparian ecosystem at any time therefore has an upstream and a downstream end, although the directionality itself may be reversed.

Diversity in wetland ecosystems seems to be inversely proportional to the length of time during the growing season that soils are saturated. Crawford (1976) pointed out that species of trees that are flood-intolerant are unable to detoxify end-products of glycolysis in the roots because of anoxia. Flood-tolerant species can either decrease glycolytic activity in anoxic conditions or detoxify the end-products of glycolysis. Several such species are capable of withstanding a short flooding period, although the longer the hydroperiod, the fewer the number of tolerant species. Wistendahl (1958) observed that slight differences in topography and depth of flooding had a significant effect on vegetation species composition in a floodplain. Franz and Bazzaz (1977) documented the narrow range of elevations within which each tree species in a floodplain is found, reflecting small but distinct differences among species not only in tolerance of mature trees to flooding but in requirements for seed germination and seedling survival as well. Among the most flexible species

of trees found in riparian ecosystems are cypress (Taxodium distichum) in the Southeast, box elder (Acer negundo) in the Southwest, and red maple (Acer rubrum) in the Northeast.

Riparian wetlands that are dominated by herbaceous plants also show zonation imposed by hydroperiod, although substrate may play an important role also. Sawgrass, wet prairie, and sloughs, for instance, are three major community types in the Everglades that are differentiated by hydroperiod, but that show site-to-site variation in species composition (Goodrick 1974).

The hydroperiod pulse may carry a pulse in nutrient input as well. However, peak nutrient availability may not necessarily coincide with peak nutrient input. Changes in pH and oxygen concentrations that accompany water level changes may affect availability of nitrogen, phosphorus, and other nutrients (see discussion by Klopatek 1978). Consequently, strategies for adapting to extremes in both moisture and nutrient availability may be common in riparian wetlands.

One unique characteristic of riparian wetlands is therefore the presence of moving water that carries with it a nutrient subsidy and that completes at least one cycle during a growing season. This pulse strongly affects both species composition and growth dynamics of the ecosystem.

Fire is another pulse that often affects riparian ecosystems. Ewel and Mitsch (1978) showed that fire is probably a common factor in many cypress ecosystems. Duever et al. (1976) suggested that in the absence of fire many of the cypress swamps in south Florida could eventually develop into mixed hardwood forest. More frequent fires would convert the swamps into shrubby marshes or sloughs. Hofstetter (1974) reported that fire is essential to the continued existence of sawgrass communities in the Florida Everglades.

Periodic incidence of fire is not restricted to southeastern riparian ecosystems. Killingbeck and Wali (1978) reported that the oldest trees in a North Dakota gallery forest were only 80 years old, even though the presence of the forest is recorded from presettlement times. They noted the observation of a long term local resident that prairie fires frequently invaded the forest, killing some of the larger trees.

When fire has been a long-term evolutionary force in an ecosystem, it very often becomes a subsidy as well, speeding decomposition and remineralization of the litter and keeping competing tree seedlings from assuming dominance (Mutch 1970). This may be particularly true in riparian ecosystems, where the effect of fire appears to be more selective than it is in upland ecosystems.

Another pulse that affects riparian ecosystems in coastal areas is provided by hurricanes, which blow in from offshore at irregular intervals, bringing high-speed winds and increased water and salinity levels many kilometers inland. A simulation model based on current biomass and metabolism data from mangrove ecosystems in south Florida predicted that these ecosystems would reach steady-state 23 years after starting from an early stage of succession (Lugo et al. 1976). These authors cited other reports on mangrove forests in south Florida and in Puerto Rico that suggested that maturity is reached after 20 to 25 years, and that the average hurricane frequency in this region is 20 to 23 years. The long-term periodic stress of high winds and subsequent increased salinity on coastal ecosystems may therefore have a strong influence on shaping metabolic patterns in an ecosystem and determining the level of complexity that it may reach.

These three pulses (flooding, fire and hurricanes) occur at short (less than one year), moderate (one to ten years), and long (20-25 years) intervals, respectively, yet each has a measurable effect on ecosystem structure and function. E. P. Odum (1971) pointed out that communities become adapted to such pulses and that their optimum function depends on them. The pattern of superposition of the variety of pulses to which a riparian wetland is exposed may clearly play a role in determining the levels of diversity and productivity that it achieves.

CONNECTEDNESS OF RIPARIAN ECOSYSTEMS

The second characteristic of riparian ecosystems that contributes to their uniqueness is their high degree of connectedness with other ecosystems. Waide and Webster (1976) reviewed the concept of connectedness, which is the number of links between organisms in an ecosystem. The concept is applied here to the next higher level, the number of links between ecosystems in a watershed. A riparian ecosystem by definition at any point receives inputs both from upstream and from the surrounding watershed and delivers them downstream, sometimes in an altered form. Nutrient and seed inputs are therefore important water-borne links between upstream (and upland) ecosystems and riparian ecosystems. Riparian ecosystems in turn may serve as seed sources for downstream ecosystems and may alter nutrient inputs as well, exporting them in more oxidized (or more reduced) forms.

Do animals provide another link between these communities? Hunt (1975) showed that terrestrial insects often form a significant proportion of the food of salmonid fishes in both lotic and lentic environments. W. E. Odum (1971) found that most of the sport and commercial finfish of the Gulf of Mexico depend at some stage in their life cycles on mangrove detritus. The rapidity with which insects reinvaded defaunated mangrove islands (Simberloff and Wilson 1969) suggests a high degree of connectedness of these ecosystems with neighboring ecosystems. Mangrove islands are not riparian ecosystems, but riverine mangroves would probably demonstrate the same response.

Bird concentrations in riparian wetlands are often very high. Hubbard (1977) reported that two river valleys in New Mexico support 16-17% of the entire breeding avifauna of temperate North America. Diversity is higher among water birds than land birds in Florida, in spite of significant losses of wetland habitat during the last century (Robertson and Kushlan 1974). Diversity of birds in a wetland is not necessarily related to vegetation diversity. Weller (1978) pointed out that variety in structure is more important than variety in vegetation composition to increasing diversity of birds nesting and feeding in marshes. Birds clearly provide important linkages between ecosystems, particularly in temperate climates where long-range migrations are common. The seasonal pattern of movement between types of ecosystems (aquatic, riparian and nonriparian wetlands, and terrestrial) is difficult to analyze, however. Nonmigratory populations may restrict their activities more to a single ecosystem. Howe (1977) described a strong relationship that had evolved between a bird and a tropical wet forest tree common in floodplain forests and theorized that plants that have specific and predictable habitat requirements and that have a particularly nutritious resource should be able to attract and establish coevolutionary relationships with foragers such as birds and insects.

Sheppe and Osborne (1971) found that less than half the species of mammals in the vicinity of the Kafue Flats along the Zambezi River regularly use the floodplain. Small mammals found on the floodplain, which is up to 40 km wide in places and floods to a depth of 5 m, either seek refuge from high water on emergent levees along the river or move long distances to the margins. Cowan and Holloway (1973) reported that 40% of the species of deer in the world that are threatened inhabit swamps, riparian forests, and floodplains that are located within a relatively arid environment. Some of these species have been able to adapt themselves to new environments, showing more plasticity than threatened species in upland environments. It seems more likely, then, that terrestrial vertebrates inhabiting riparian wetlands either restrict their movements to these areas or perhaps move outward into surrounding areas to feed. But upland vertebrates seldom invade the wetland areas.

Connectedness with upstream and downstream ecosystems is therefore an important characteristic of riparian wetlands. Most of the flow of energy and nutrients seems to be water-borne, but animals may provide significant linkages with surrounding ecosystems as well. Net energy flows associated with animal populations seem to be from upland to wetland ecosystems and from wetland to aquatic ecosystems.

STABILITY OF RIPARIAN ECOSYSTEMS

Waide and Webster (1976) conducted an analysis of the effects of different levels of connectedness on ecosystem stability, using a linear model for their analysis. They analyzed neighborhood stability, which is related to the magnitude of the response of the system to its forcing functions. They concluded from this analysis that when interrelationships in an ecosystem are primarily donor-controlled, rather than recipient-controlled, higher degrees of connectedness lead to greater stability. Their hypothesis is applicable at the watershed level, and the relationships between ecosystems in a watershed may actually fit a linear model more closely than do the relationships between organisms in an ecosystem. The primary linkages in a watershed are the unidirectional flows of water-bearing nutrients. Linkages provided by animal movements are nonlinear (e.g., simultaneously donor and recipient-controlled) but are probably less significant to the total energy flow.

Waide and Webster's analysis suggests that wetlands that are fed by more diverse watersheds may have higher stability. This is supported by the observation that terrestrial vertebrates in particular may move out from riparian wetlands but not necessarily into them, recalling Margalef's (1963) principle that energy tends to flow toward the more mature system in a mosaic of different systems, and assuming that greater stability comes with maturity.

Stability, however, may also be evaluated as the response of a system to a human-induced perturbation. In the analogy between an ecosystem and a watershed, the river and associated wetlands that drain the watershed may be equivalent to top carnivores, since water and the nutrients it carries converge on these ecosystems in the same way that energy in the stricter sense converges on the higher

trophic levels (H. T. Odum, in press). Presumably, top carnivores would suffer more than lower trophic levels from perturbations affecting the ecosystem (see discussion in Ricklefs 1976). Riparian wetlands, therefore, may be relatively stable in an unperturbed world, but actually occupy sensitive niches in the watershed system when human-induced perturbations are considered.

Stability relative to such perturbations is believed to be comprised of two components: resistance and resilience (Webster et al. 1975). Resistance is defined as the ability of an ecosystem to withstand change from perturbation, and resilience is the ability of an ecosystem to return to its initial state after change induced by perturbation. Management of riparian ecosystems must therefore take into account both aspects of stability in determining the overall impact of management practices.

MANAGEMENT OF RIPARIAN ECOSYSTEMS

The benefits provided by riparian ecosystems can be summarized as: 1.) benefits that can be taken advantage of without destroying the essential characteristics of the ecosystem (fish and wildlife production, flood control); and 2.) benefits that may be extracted from the ecosystem only by leaving a scar of variable magnitude and duration (navigation, reservoir siting, timber production). The stability of each of the major kinds of ecosystems will be analyzed with respect to its abilities to provide the second class of benefits.

Hydroperiod Manipulation

Changes in hydroperiod may be brought about by either direct or indirect actions. Direct actions would include flooding or draining of the basin, and evaluation of their effects may be fairly straightforward. Channelization moves water more rapidly from upstream to downstream, and might drain the surrounding riparian ecosystem, allowing establishment of upland species. However, development that occurs elsewhere in the watershed may also have significant effects on water flows, such as by increasing runoff or diverting runoff directly into a water source. Zoning of land use activities and development clearly must be implemented on a watershed basis in order to guard more effectively against these indirect effects.

The most sensitive characteristic of riparian ecosystems is clearly the dependence of species composition on hydroperiod and depth of flooding. Disturbance of hydroperiod may drastically change the ability of floodplain species to maintain their dominance. It is apparently not always possible to detect the seriousness of a change until trees die; many will continue growth and not demonstrate stress until their abrupt death (Green 1947). Tolerances of individual species to changes in hydroperiod have been documented (see review by Gill 1970), and it should be possible to rank the tolerances of different floodplain communities to change.

Community tolerance may be inversely proportional to diversity. In the Southeast, cypress-dominated ecosystems may sustain the longest hydroperiod, but there are clearly limits to their flexibility: regeneration is not possible without an occasional complete drawdown, and significant increases in depth may not be tolerated for long period. Both forested and herbaceous wetlands are probably equally intolerant to flooding and drainage, since in both cases decreased hydroperiod would make a site habitable to far more species. Resistance and resilience to changes in hydroperiod may therefore be low. Resilience may actually be lower than resistance because germination and growth requirements of seedlings are often more stringent than survival requirements of the adult plants. However, if the original hydroperiod is restored, resilience may be fairly high.

Increased Nutrient Loading

Wetlands are currently favored sites for testing the ability of natural ecosystems to absorb the nutrients in secondarily treated wastewater, reducing the need for constructing expensive advanced wastewater treatment systems. Both forested and nonforested wetlands throughout the country have proven to be able to absorb excess nutrients without substantial harm to ecosystem structure or function. Nessel (1978) showed that cypress trees in a sewage-enriched cypress strand sustained increased growth rates for more than 40 years. Both ash and cypress increased growth rates over a 20-year period in a swamp containing ash, (*Fraxinus profunda*), cypress, and black gum (*Nyssa sylvatica*) trees (Boyt 1976). Sloey et al. (1978) reported continued reduction of nitrogen and phosphorus levels in agricultural runoff going through a marsh over a 50-year period, during which phosphorus appeared to accumulate in the sediments.

In short term studies, net productivity of a freshwater marsh increased over a one-year period of sewage application in central Florida (Dolan 1978). Whigham and Simpson (1976) found that some herbaceous species in a freshwater tidal marsh were eliminated from enclosures receiving effluent. Wentz (1976) reported no significant effect of sewage effluent disposal on species composition in a Michigan peatland.

In all cases, sediments appeared to serve as the primary nutrient sink. In the sewage-enriched systems, nutrient concentrations increase in the foliage of the trees and in roots of both trees and herbaceous species. Dorge (1977) found that phosphorus storage in the sediments of a riverine cypress swamp in Illinois far exceeded storage in all other compartments in the ecosystem. Sediments in riparian ecosystems therefore appear to be the primary absorbing unit in both undisturbed and sewage-enriched riparian ecosystems. However, some river swamps may have little or no sediment accumulation, although it is not clear whether increased nutrient loading would damage such systems.

Riparian ecosystems seem to be capable of tolerating increased nutrient loading without substantial changes in tree species composition, although composition of herbaceous species may change. Sediments appear to be capable of storing large quantities of phosphorus in particular. Restrictions on use of wetlands for sewage disposal are probably more closely related to detrimental effects of increased hydroperiod than to nutrient loading itself.

Fire Regulation

Changes in fire periodicity and/or severity may be critical. Gunderson (1977) found that periodic surface burns tend to arrest succession in a cypress swamp, but that a severe burn caused by increased growth rates of understory because of logging or drainage may completely destroy both hardwood and cypress stands. Both too much and too little fire must therefore be guarded against. However, because fire periodicity is usually more random than hydroperiod, small changes may be less damaging.

Resistance to change in fire periodicity in an otherwise unperturbed system may be moderate. Increased fire incidence will destroy fuel resources and may prevent seedling establishment. Decreased fire incidence may allow fuel to accumulate, increasing the severity of a subsequent fire. Resilience, however, will depend on the existence of a seed source. Any portion of a riverine system may therefore be resilient as long as propagules are continually washed from upstream to replace losses from downstream sections. Herbaceous ecosystems that depend more on wind or animals to transport propagules may be more resilient. Least resilient are upstream portions of ecosystems and ecosystems with large areas and slow flows, where migration of propagules to the burned area may be slow. Resilience in any riparian ecosystem will decrease with the severity of the fire, especially if peat beds are destroyed (Ewel and Mitsch 1978).

Some geographic areas, such as the Southeast, are clearly more sensitive than others to changes in fire periodicity. Hofstetter (1974) pointed out that lightning-caused fires in Florida were historically most common during the summer wet season, and probably did not cause extensive damage. Charcoal and ash deposits that have been found deep in peat deposits indicate that fires occasionally started before the summer rains or during an exceptionally dry spell and probably were very destructive. The combined effect of increased incidence of human-caused fire and lowering of water tables has been far more dry season fires, which tend to be much more destructive. In areas such as the prairie states where fire is presently less prominent an ecological factor than it was in the past, it would be useful to document the effect of fire removal on the remaining natural ecosystems.

Timber Harvest

Bottomland hardwoods and floodplain forests have traditionally been favored sites for harvesting timber. However, removal of most of the large old trees in the late nineteenth and early twentieth centuries was an extractive process, and sustained yield was not an object. Moreover, dikes built to gain access to trees in the broader forests often affected water flow patterns. Resistance to timber harvest actually depends only on accessibility of the timber, and few large swamps have not been cut over at least once.

Resilience of floodplain forests seems to be fairly high, although a combination of high-grading and site alteration may have increased regeneration time for many of the forests. Lee (1945) found that canopy closure in forests growing on natural levees in floodplain forests in Indiana occurred after 36 years. Turner (1931) reported that American elm (Ulmus americana) and silver maple (Acer saccharinum) achieved dominance in 40 years in communities developing on artificial levees along the Illinois River. Cottonwoods (Populus deltoides) 40 feet tall were found together with black willow (Salix nigra) on a 15-year-old island in the Wabash River (Lindsey et al. 1961). During the first winter after a drawdown of the Rodman Reservoir in the former basin of the Oklawaha River, Florida, cypress seedlings proliferated along the banks, suggesting that forest regrowth would be fairly rapid if the natural hydroperiod were restored. When a forested area upstream of a harvested area is left intact, it will act as a seed source for downstream areas. If these riverine forests are habitats for rare or endangered populations, however, removal of large sections of forest should be avoided.

Mangrove forests are able to recover rapidly from localized cutting. However, changes in salinity that may accompany drainage and cutting may reduce seed germination (Holdridge 1940).

Resilience in forests with a broad expanse and little topographical change may be more dependent on seed storage in the sediments and less on upstream seed sources. Alteration of water flow by diking may decrease seed access to all areas of the swamp and may cause ponding, decreasing the probability that seeds will germinate. Construction of dikes should therefore either include culvert systems or be oriented to disturb water flow patterns as little as possible. Clear cuts in such areas should be restricted to small areas so that seed transportation is rapid. One large paper company in Florida is currently experimenting with the use of 16-hectare clearings in bottomland swamp. Their plan includes a rotation scheme and buffer strips. Such a design may be economical on a long-term basis, especially if buffer strips can be chosen specifically to include seed trees of the most desireable species.

CONCLUSIONS

One unique characteristic, hydroperiod (and, in some cases, fire), determines the resistance of the community. The shorter the hydroperiod, the less tolerant an ecosystem will be to an increase in hydroperiod; decreasing hydroperiod will probably cause changes in any riparian ecosystem. Another unique characteristic, connectedness, determines resilience. Connectedness, however, is a double-edged sword, for while it ensures seed and nutrient inflow after a disturbance, it also increases the battery of impacts to which an ecosystem may be exposed. In preserving the roles that these ecosystems play in a watershed, therefore, the periodic influence of flooding and fire must be maintained. Connectedness may be depended upon to speed regrowth of a harvested ecosystem, but its effect on increasing sensitivity to impacts generated elsewhere in the watershed must be recognized as well.

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Interactions Between a Riparian Swamp and a River in Southern Illinois[1]

WILLIAM J. MITSCH[2]

Abstract.--A study of a 30 hectare Taxodium distichum-Nyssa aquatica alluvial swamp emphasized the swamp's interactions with the adjacent river. The swamp and river chemistry were compared and chemical losses from the swamp to the river were calculated. Analysis of tree growth suggests a connection between swamp productivity and flooding frequency. Economic calculations were used to determine the replacement value of the swamp for two of its public service functions.

INTRODUCTION

A major ecosystem of the riparian environment in the Coastal Plain province is the backwater or alluvial swamp. These swamps represent areas of stagnant or flowing water caused by abandoned river meanders or similar geological phenomena. The structure and function of such ecosystems are intimately tied to the swamp's hydrologic conditions and nutrient inputs. In the Southeast and as far north as Illinois and Indiana in the Mississippi River Valley these systems are often dominated by cypress (Taxodium distichum) and swamp tupelo (Nyssa aquatica) with the understory rich in aquatic life and vegetation growing on tree stumps and floating logs.

The connections between these wetlands and the adjacent stream or river make the alluvial swamp a very productive ecosystem. The river dictates water level through the control of adjacent groundwater levels and through occasional floods. Furthermore, the flooding leaves behind sediments rich in nutrient material that are utilized by the ecosystem in achieving very high productivities. This study involves a systems view of an alluvial cypress swamp in southern Illinois, emphasizing the swamps interactions with the adjacent river.

[1]Paper presented at the National Riparian Ecosystem Symposium, Calloway Gardens, Georgia, December 11-13, 1978.

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STUDY SITE

Heron Pond (fig. 1) is a 30 ha bald cypress-tupelo swamp in Johnson County, Illinois, adjacent to the Cache River. The swamp is separated from the river by a natural levee. It is normally 2 to 3 m above river elevation except during flooding. The river watershed covers 1912 km^2 in the six southernmost counties in Illinois and originates in the hills of the Shawneetown Ridge, an east-west escarpment of the Pennsylvanian glaciation (Voigt and

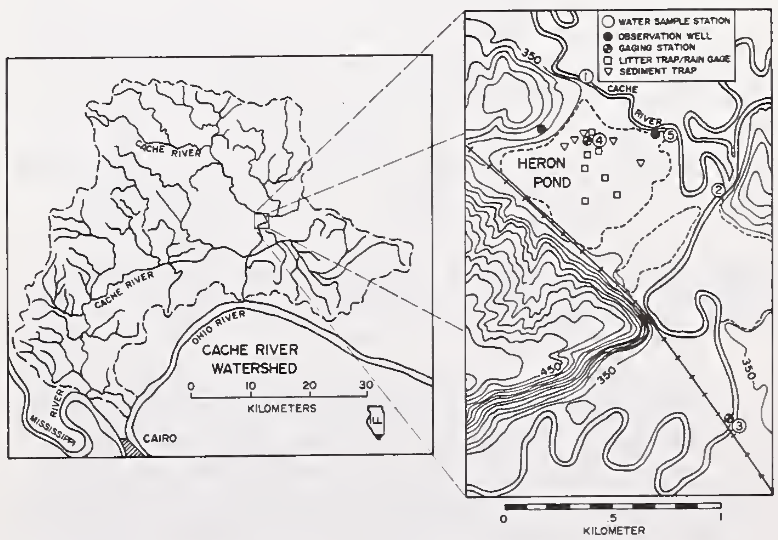

Figure 1.--Heron Pond/Cache River study site in southern Illinois, showing gaging and sampling stations.

Mohlenbrock, 1964). As the Cache reaches the lower half of its course out of the Shawnee Hills, the land suddenly flattens and the drainage conditions change to slow flowing and meandering channels and numerous wetlands characteristic of the Coastal Plain. Our measurements found 48 km^2 of wetlands in the Cache River basin. Much of the lower Cache River flows in an abandoned channel of the Ohio River and its inundated by the Ohio River itself on an average interval of 100 years (Gooding, 1971).

Anderson and White (1970) conducted a floristic study of the swamp. Taxodium distichum and Nyssa aquatica dominate the canopy, while two species of duckweed Spirodela Polyrhiza and Azolla mexicana coat the water surface from May through October. Heron Pond receives drainage from 104 ha of forested upland, dominated primarily by Quercus alba L., Q. muehlenbergii Englm., Q. rubra L. and Carya glabra (Mill.) Sweet. A train trestle, running from northwest to southwest, is the only obvious cultural feature in the Heron Pond watershed. Heron Pond has experienced several disturbances in the past including logging and beaver activity. Channelization of the Cache River, both upstream and downstream of the swamp, and the diversion of some of the Cache River flow to the Ohio River may be accelerating stream erosion and lowering swamp water levels.

METHODS

Description of the methods used in this study are given in Mitsch et al (1977) Dorge (1977) and Wiemhoff (1977).

SWAMP HYDROLOGY

The annual hydrology budget for Heron Pond for the study period is shown in figure 2. These flows resulted from an annual precipitation of 105cm. Inflows included 74.3 cm as throughfall, 69.4 cm as runoff and stemflow, and 21.6 cm as groundwater. Outflow included 72.3 cm as evapotranspiration, 55.5 cm as surface flow and 21.0 cm as groundwater outflow. These latter two flows carried water to the adjacent Cache River.

A flood occurred on March 28-April 1, 1977, when the Cache River overflowed its banks and inundated the swamp. It was determined through analysis of water level records that the swamp was flooded due to precipitation and runoff shortly before the river exceeded bankfull discharge; thus while the river passed an enormous volume of water over the swamp, it is assumed that it did not contribute any net increase of water to the swamp after it receded. It was estimated that approximately $1.6x10^7 m^3$ of river water passed over the swamp. The swamp water increased to about 2.3m depth, over 1.6m deeper than normal. This flood was determined to have a return period of 8 years.

The surface outflow from Heron Pound continued to contribute significant flow to the Cache River as late as May and June (fig. 2), well after the flood. This affirms the value of these wetlands as storage sites which capture water during times of high water and re-

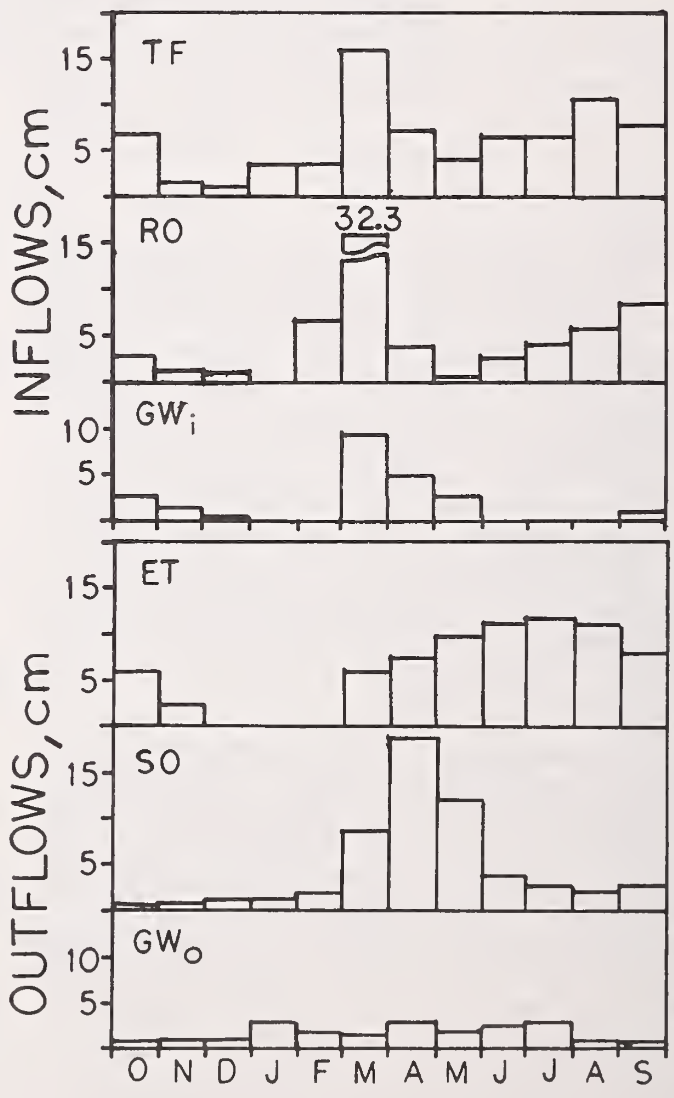

Figure 2.--Monthly inflow and outflow components of Heron Pond's annual water budget. TF = throughfall, RO = runoff into swamp, GW; = groundwater into swamp, ET = evapotranspiration, SO = surface outflow, and GW_o = groundwater outflow.

Table 1.--Water Chemistry Averages and Ranges for Heron Pond and the Cache River During the Study Period

Parameter	Heron Pond n[1]	Heron Pond $\bar{X}$[2]	Heron Pond Flood	Cache River n[1]	Cache River $\bar{X}$	Cache River Flood
Dissolved Oxygen, mg/l	5	$\underline{2.2}$	-	8	8.9	-
pH	4	$\underline{6.1}$	-	11	7.3	-
alkalinity, mg $CaCO_3$/l	9	31	12	27	99	32-52
ortho-phosphate, mg-P/l	9	0.16	0.16	27	0.15	0.05-0.14
total soluble P, mg-P/l	9	0.19	-	25	0.20	-
total P, mg-P/l	10	0.47	1.81	28	0.53	0.72-2.12
NO_2^-, mg-N/l	6	$\underline{<0.01}$	<0.01	18	0.02	<0.01-0.06
NO_3^-, mg-N/l	6	$\underline{<0.01}$	<0.01	18	0.09	<0.01-0.09
NH_4^+, mg-N/l	6	1.00	0.18	15	0.27	0.08-0.24
Total Kjeldahl Nitrogen, mg-N/l	6	1.64	0.60	18	0.97	0.5-1.0
Ca^{++}, mg/l	7	$\underline{6.6}$	4.1	21	27.6	3.7-6.0
Mg^{++}, mg/l	7	$\underline{2.4}$	2.5	21	5.7	2.4-2.7
Na^+, mg/l	7	$\underline{3.2}$	2.7	21	14.5	2.4-3.1
K^+, mg/l	7	$\underline{3.3}$		21	5.9	3.0-3.2
$SO_4^=$, mg-N/l	4	$\underline{2.7}$	7.0	15	15.9	8.5-13.1

[1]Number of separate sample dates at all stations.

[2]Underline indicates swamp values that are significantly lower than river values for data from same sampling dates (paired t-test, α = 0.05).

lease it more slowly during drier periods. It was found that the water level of the river receded to half its peak level in 5 days while it took the swamp 59 days to drop to half of its flood depth (Wiemhoff, 1977).

SWAMP-RIVER WATER CHEMISTRY COMPARISON

Water chemistry data from Heron Pond and the Cache River are summarized in Table 1. Total phosphorus remained similar in the swamp and the river for much of the non-flooding year (generally between 0.2 and 0.6 mg P/l). Paired values showed no significant difference for the sample period (α = 0.05). However, during high flow conditions of March 5 (when the river came within 1 m of exceeding its banks) and during the flood of April 1, total phosphorus levels of the river were much higher. The March 5 river samples averaged 1.33 mg P/l. On March 5, because the river did not crest high enough to flood Heron Pond, total phosphorus in the swamp remained low (0.47 mg P/l); however, when the swamp was flooded on April 1, a phosphorus value of 1.81 mg P/l was measured. This

was within the range of values seen in the flooding river. Because the orthophosphate and soluble phosphorus forms remained nearly constant throughout the study period, it is probable that high phosphorus concentrations during flooding are associated with suspended material being carried by the flood waters. Stumm and Leckie (1971) and Golterman (1973) discuss some of the ways in which phosphorus is bound into clay particles, probably a significant phosphorus transport mechanism in the Cache River.

There were considerable differences between Cache River and Heron Pond dissolved substances during the non-flooding period (figure 3). The swamp had significantly lower ($\alpha = 0.05$) levels of calcium, magnesium, sodium, potassium and sulfate. When the spring flooding occurred, the dissolved ions decreased dramatically in the river. The swamp water displayed relatively constant levels of calcium, magnesium, and sodium compared to the widely fluctuating levels found in the river; the diluted flood waters resulted in very little change in these dissolved ions in the swamp. The calcium and bicarbonate ions (the latter calculated from alkalinity) showed slight increases in the swamp after the flood, perhaps, as a result of continued groundwater flow to the swamp in April and May (fig. 2). By the end of July, all of the above ions decreased to their lowest post-flood concentrations as throughfall and surface runoff dominated the swamp hydrology.

The very low levels of sulfates in Heron Pond during the non-flooding times (1.6 mg S/1) reflected the reducing environment in the swamp; disturbance of sediments in the swamp often released noticeable levels of hydrogen sulfide gas. Sulfate, interestingly, increased in the swamp with spring runoff and flooding, indicating the less reduced conditions produced by the deeper and more oxygenated flood waters. Sulfates contributed by rain, runoff and flooding waters are quickly reduced to hydrogen sulfide in the swamp. This sulfide may be retained in the anaerobic layers of the swamp indefinitely or may be released back to the atmosphere. Further study of the sulfur dynamics of these swamp systems is needed.

CHEMICAL LOSSES FROM THE SWAMP

Except for the brief flooding period, there was a continual flow of water from the swamp to the river as channelized surface flow and as groundwater. Conveniently, most of this flow was isolated in the stream at Station 5 (fig. 1) allowing for estimations of the chemical losses from the swamp to the Cache River. These values are of interest to determine if the cypress-tupelo swamp is a leaky system compared

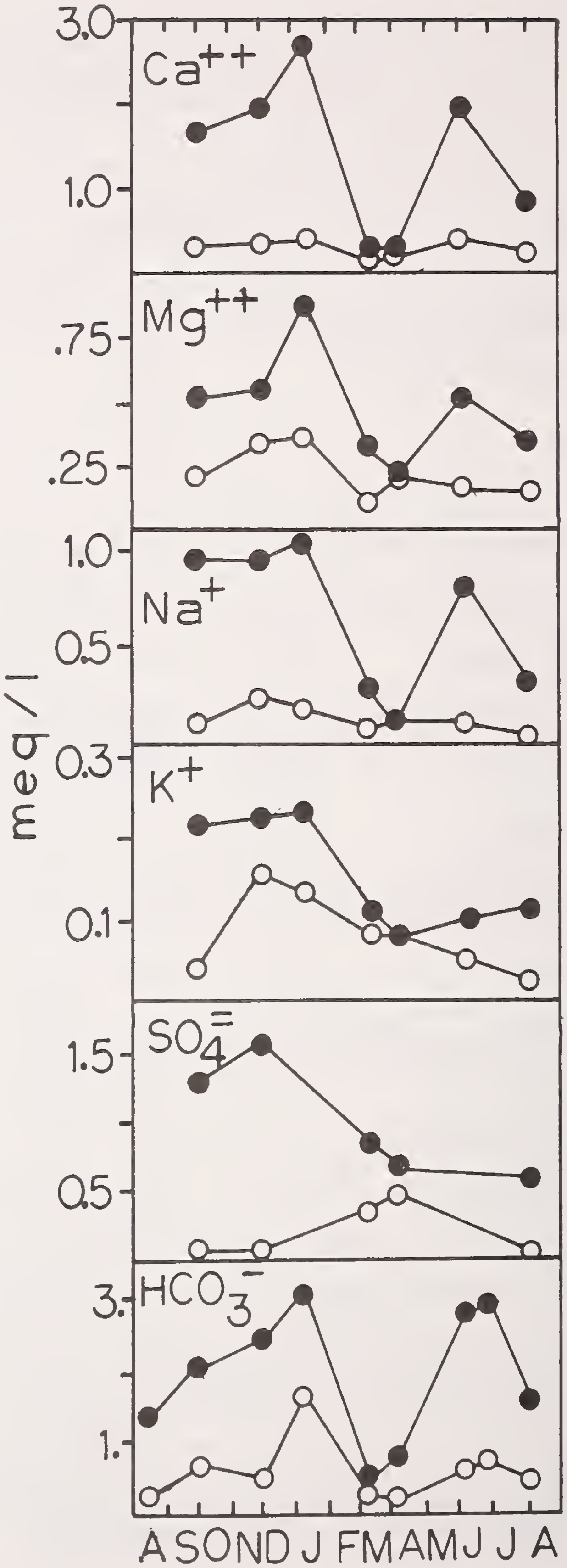

Figure 3.--Comparison of dissolved ions in Heron Pond and the Cache River for the study period. The river data are given in darkened circles (●) while the swamp data are in open circles (O). The flood at the end of March led to mixing of swamp and river waters, minimizing their difference in concentrations.

Table 2.--Comparison of Heron Pond Watershed Chemical Losses with Other Temperate Ecosystem Watersheds. Values are in kg/ha-y.

Parameter	Wetland-Dominated			Angiosperm-Deciduous Forest		
	Heron Pond[1]	Louisiana Swamp-Marsh[2]	Rough Sike, England[3]	Hubbard Brook N.H.[4]	Missouri Ozarks[5]	
					W.S. 1	W.S. 4
Total P	0.76	3.9	0.4	0.02	0.15	0.05
NO_3+NH_4 (as N)	1.13	-	-	4.0	2.34	1.52
Total N	2.3	27.0	2.9	-	-	-
$SO_4^{=}$-S	11.0	-	-	17.6	-	-
Ca^{++}	10.7	-	53.8	13.9	7.1	76.2
Mg^{++}	4.2	-	-	3.3	4.0	51.6
Na^{+}	4.6	-	45.2	7.5	3.7	4.5
K^{+}	5.2	-	9.0	2.4	3.9	4.7

[1]this study; includes upland that drains into Heron Pond.

[2]Day et al. (1977); includes some contribution from agricultural runoff.

[3]Crisp (1966); does not include transport of eroded peat.

[4]from Likens et al. (1977).

[5]Settergren et al. (1976); W.S. 1 is runoff-dominated water shed, W.S. 2 is spring-fed watershed.

with other terrestial ecosystems or if it retains its minerals and nutrients. Its role in either augmenting or reducing chemical flows from the surrounding uplands is also of interest.

The estimated chemical losses from Heron Pond are compared with gross outputs from other wetland and terestrial ecosystems in Table 2. The Heron Pond value includes the 104 ha of uplands that make up the swamp's watershed and drain into the swamp. The values for Heron Pond are representative of the chemical losses from the Heron Pond to the Cache River, although they do not take into account any minerals that would be filtered out by the soil or picked up by the groundwater flow as it passes through the levee into the river. Surface losses were generally three times higher than groundwater losses. Few data exist on chemical discharges from wetland-dominated watersheds. Day et al. (1977) report on estimated nitrogen and phosphorus export from a watershed dominated by cypress-tupelo and bottomland hardwoods. Their values are an order of magnitude greater than those found in this study, indicating the high flux of nutrient materials through the Lousiana lowlands to adjacent estuaries. Day et al. (1977) considered the flooding season in their calculations and also indicated that some of the nutrient contribution is probably from agricultural runoff. A study of a Pennine moorland (Crisp, 1966, summarized in Moore and Bellamy, 1974) gave comparable nitrogen and phosphorus outputs, but much higher loadings of dissolved cations. This area is described as 83 ha of blanket peat fed by springs from peat channels and limestone rock; this would explain the high calcium discharge there.

Comparison with the extensive mineral budgets determined for Hubbard Brook, New Hampshire (Likens et al., 1967, 1970. 1977) is also of interest. At Hubbard Brook, the nutrient outflows were a function of the precipitation inputs, geological weathering of minerals, and the retention by the forested ecosystem. The Heron Pond watershed has all of these factors but has, in addition, the continual influx of nutrients and sediments from the flooding river. Phosphorus discharge from the Heron Pond watershed is 38 times higher than that from Hubbard Brook, reflecting the rich conditions created by the flooding Cache River. Inorganic nitrogen loading from Heron Pond is 28% of that found at Hubbard Brook, thus reflecting the volatile nature of nitrogen in the swamp environment. Sulfate loading from Heron Pond was also somewhat less for the same reason, although the Heron Pond value is based on few data. Sulfur in the form of sulfide leaving the swamp was not measured. Divalent cation gross loadings were similar in both studies. For monovalent cations, potassium discharge was more important at Heron Pond while sodium is greater at Hubbard Brook. This reflects the low Na:K ratio found in the flooding Cache River and the relative

proximity of the Hubbard Brook ecosystem to the ocean.

The only known nutrient budget study close in location to Heron Pond was described by Settergren et al. (1976) for the Missouri Ozark Mountains. A watershed there dominated by surface runoff gave similar cation values, although one dominated by spring-fed streams gave much higher export values for calcium and magnesium. As was the case with Hubbard Brook, phosphorus export was less and nitrogen export more in the Ozark study than the Heron Pond watershed.

SWAMP SEDIMENTATION

Ten sediment traps were installed in the swamp to investigate annual autochthonous sedimentation due to biological productivity in the swamp and to measure allochthonous sedimentation due to the flooding river. The organic and inorganic fractions of the measured sedimentation are shown in figure 4.

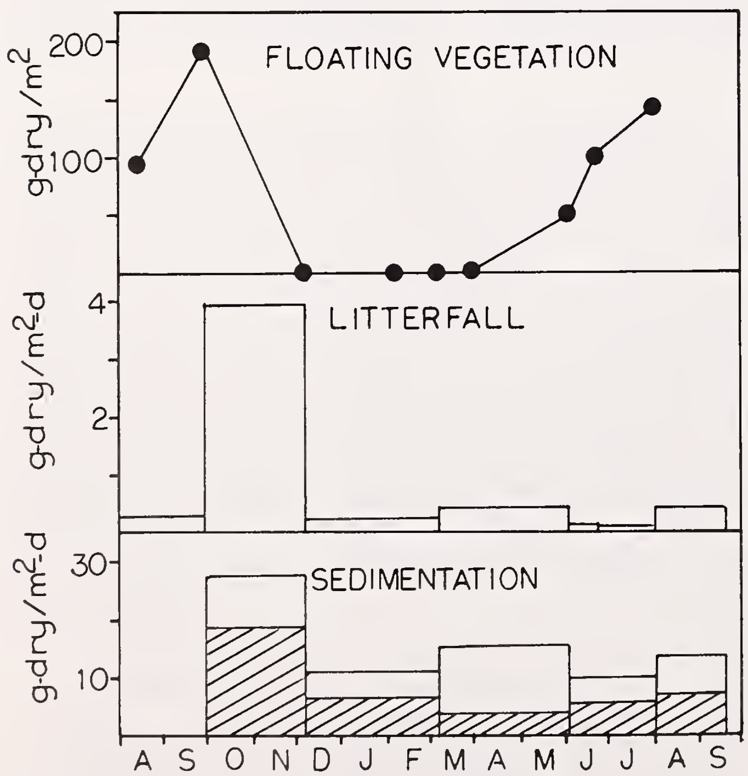

Figure 4.--Floating duckweed biomass, canopy litterfall and sedimentation rates measured in Heron Pond during study period. Shaded portion of sedimentation graph indicates organic fraction.

The highest rates occurred in autumn during the time of maximum litterfall and duckweed dieoff. Less noticeable peaks occurred in spring and late summer. Deposition for the year was calculated to be 5.6 kg dry wt/m^2-y with organic content averaging 52%. Thirty one percent of total sedimentation and 41% of organic sedimentation occurred during the months of October and November.

The flooding river contribution to sedimentation in the swamp was calculated as the excess over the average sedimentation rates from the preceding and following sampling periods leading to an estimate of 447 g dry wt/m^2. It was estimated that the flooding river passed approximately 15 kg/m^2 of sediment over the swamp during the flood,indicating that 3% of this lead settled out in Heron Pond. Using the average bulk density measured in the sediment cores of Heron Pond, the flood contributed 0.06 cm of sediment to the swamp. Stated another way, if this flood occurred every year (it does not, but was determined to have an annual recurrence interval of 8 years) 6 cm of sediments would be deposited in 100 years. By comparison, Eckblad et al. (1977) found a recent sedimentation rate of 1.7 cm/y in a backwater lake of the Mississippi River. That study's rate reflects, however, autochthonous inputs as well as inorganic sedimentation due to flooding.

A total phosphorus deposition of 15.7 g P/m^2-y was estimated from the sediment trap data. Of that total, 3.6 g P/m^2 was calculated as excess deposition over normal conditions that was contributed by the flood. When sedimentation is expressed in terms of phosphorus, the highest rate was experienced during the flood period, not during autumn. This value is significant when compared with the overall input from rainfall, runoff, and groundwater (0.2 g P/m^2-y) and when compared to the swamp discharge to the river (0.34 g P/m^2-y). Thus the swamp received 18 times more nutrients due to the flooding river than from all other inputs and it discharges less than a tenth of that back to the river.

SWAMP PRODUCTIVITY

The continual influx of nutrients from the flooding river should have a positive effect on the productivity of the swamp. This effect was measured two ways: 1) comparison of calculated net primary productivity of Heron Pond with other wetland ecosystem, and 2) determination of flood frequence effects on cypress tree growth.

Productivity Comparison

The net primary productivity of Heron Pond was dominated by a canopy of cypress and tupelo

Table 3.--Distribution of Net Primary Productivity in Heron Pond

Component		Net Primary Production, g dry wt/m^2-y	% of Total Production
Trees		861	44
Cypress & Tupelo Litterfall	348		
Cypress Wood	193		
Tupelo Wood	137		
Cypress Roots	107		
Tupelo Roots	76		
Aquatic Vegetation		1097	56
Herbaceous Vegetation		5	<1
Total		1963	100

and an understory of the duckweeds, Spirodela polyrhiza and Azolla mexicana. Patches of other understory vegetation growing on old tree stumps and floating logs also contributed in a minor way to the swamp's productivity. The distribution of the net productivity of the swamp is given in Table 3. The total litterfall was 348 g dry wt/m^2-y and its annual distribution is given in figure 4. The litterfall is much less than the value obtained by Conner and Day (1976) in a cypress-tupelo swamp in Louisana (620 g dry wt/m^2-y) and is similar to the 310 g dry wt/m^2-y found by Schlesinger (1978) in the nutrient-poor Okefenokee Swamp in Georgia.

Overall above ground wood productivity was 330 g dry wt/m^2-y, 58% due to Taxodium. When the root estimation is included, the wood productivity is 513 g dry wt/m^2-y. Conner and Day (1976) found an above ground production of 500 g/m^2-y for their Louisiana swamp, while Mitsch and Ewel (in press) gave an average of 289 g dry wt/m^2-y for cypress in cypress-tupelo swamps in central Florida. The maximum standing crop of duckweed, 200 g dry wt/m^2, was measured in early October at the end of the growing season (fig. 4). Biomass was zero during the winter months with about 18 cm of ice on the swamp for much of the winter. Weighted average biomass was 67 g dry wt/m^2 and ranged between 100 and 200 g dry wt/m^2 for most of the growing season.

Total aquatic net productivity was estimated from sedimentation measurements, after allowing for resuspension, to be 1097 g dry wt/m^2-y. Productivity was attributed primarily to the duckweed; it was assumed that the presence of the dense mat of duckweed during the growing season precluded any significant water column productivity although occasional dense semi-submerged mats of Ceratophyllum demersum were encountered in the swamp. Productivity from other understory vegetation was estimated by a harvest of new growth at the end of the growing season and was found to make a minor contribution.

Total swamp net primary productivity is thus estimated to be 1963 g dry wt/m^2-y. Aquatic productivity, mainly from duckweed, was 55.9% of the total. When compared with other forested wetlands, the overall productivity is high. Reiners (1970) found 1070 g dry wt/m^2-y for a Minnesota cedar swamp while Conner and Day (1976) estimated the total productivity of the Louisiana cypress-tupelo swamp to be 1140-1516 g dry wt/m^2-y. Schlesinger (1978) found a very low above-water productivity of 692 g dry wt/m^2-y for the Okefenokee Swamp in Georgia, reflecting the low nutrient conditions there. A cypress dome receiving high nutrient sewage was estimated to have an overall productivity of 1530 g dry wt/m^2-y, much of that production due to a mat of duckweed on the water's surface (Odum et al., 1977)

However, tree productivity is low for an alluvial swamp of this type, and raised water levels may have caused this decrease in productivity. Few cypress seedling were seen under the canopy; cypress seedlings need a period of dry conditions in which to germinate (Demaree, 1932). Although the swamp is at the northernmost extreme for cypress wetlands, it appears to have the potential for productivities equal to those of more southern climes. The high water levels have selected for aquatic productivity in lieu of tree productivity.

Cypress Tree Growth And Flooding Frequency

Figure 5 gives an interesting relationship found between cypress tree growth, as measured by tree core analysis, and river flooding, as measured by annual river discharge. Each data point represents a five year period. Correlation between cypress growth and river flow was very good when the period 1937 to 1966 was analyzed. The correlation is less significant when data before that time or after that time are included. In both of these periods (1927-36 and 1967-76) cypress tree growth remained low despite a range of river discharges. For the later period, the low productivity was probably due to beaver population that invaded the swamp and raised water levels. The fact that tree mortality occurred during this time in Heron Pond is documented (Anderson and White, 1970). The low productivity of the 1927-36 is more difficult to explain, but considerable logging activity may have occurred in the swamp during this time.

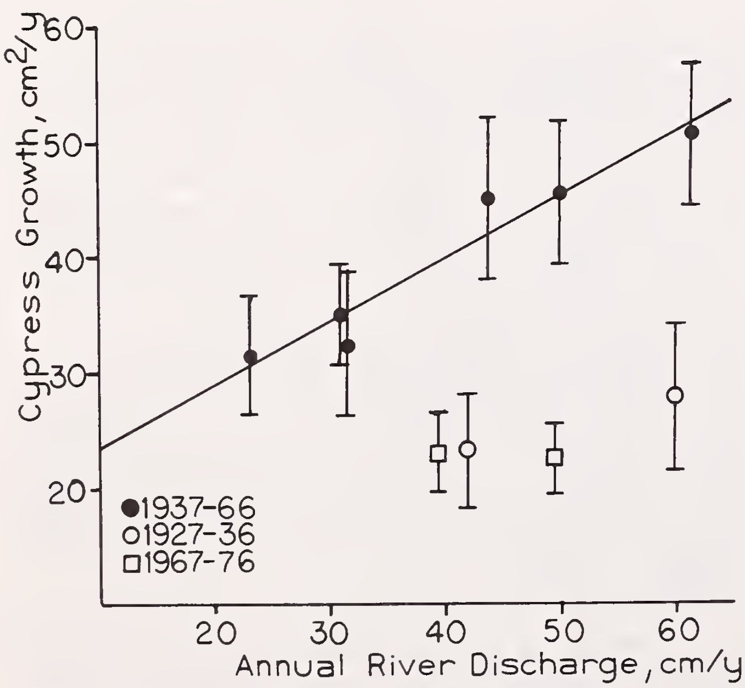

Figure 5.--Cypress tree increase in basal area from Heron Pond as a function of average Cache River discharge for five year periods. Straight line is for data from 1937-66 only ($r = 0.97$).

The results in figure 5 nevertheless suggest a significant connection between the floodplain ecosystem and the adjacent river. The river overflows its bank, heavily laden with sediments, and deposits them in the swamp. The sediments are high in phosphorus, a vital nutrient for any ecosystem. The fact that cypress growth may be dependent on the flooding river shows vividly an example where management of one ecosystem can dramatically affect another. Flood control and channelization measures in the Cache River could be to the detriment of this alluvial cypress swamp.

ECONOMIC ANALYSIS

The value of these types of riparian ecosystems to man has been partially demonstrated in this study. The swamp retained floodwaters that would otherwise crest even higher peaks of floodwater downstream. The swamp also retained a considerable amount of nutrients that were deposited by the flooding river. These nutrients, as measured only by phosphorus in this study, have thus been prevented from remaining in the river system, possibly to contribute to eutrophication problems downstream.

One approach to determine the value of their function, both in terms of energy and money, is to determine the costs that man would incur if he had to do the same functions. The energy costs for equivalent phosphorus removal and for flood control are shown in Table 4. The 587×10^6 kcal/yr of energy required for these two processes is equivalent to 414 barrels of oil per year. The total cost in dollars of these projects would be $18,000/yr. Thus we can suggest that the 75 acre cypress-tupelo swamp in our study performed functions that were worth 5.5 barrels of oil per acre per year and $240 per acre per year. There are most probably more functions of wetland such as these that can be translated into economic and energetic value. These may include value as nitrogen and sulfur recycling systems, value in the prevention of droughts downstream, and values as a habitat and spawning area for aquatic and terrestrial organisms that migrate to the river or the upland.

SUMMARY

This study of an alluvial cypress swamp in southern Illinois and its interactions with the adjacent river allows for some general conclusions about the structure and function of these wetland ecosystems:

1. The swamp was a significant sink for phosphorus during the study period. The flooding river contributed over ten times more phosphorus as sediments than was discharged to the river during the remainder of the year. The continual high input of nutrients makes this type of swamp

Table 4.--Substitute Energy and Money value of Heron Pond

Value	Energy Value (10^6 kcal FFE/yr)	Money Value ($1000/yr)
Nutrient Removal (P-removal)	261[1]	2.28[2]
Flood Control	326[4]	16.21[3]
TOTAL	587	18.49

[1]Based on 3.6 g P/m^2-yr removed from river by swamp and energy cost of P-removal technology of 36.1 BTU/gal (Khan, 1977).

[2]Based on $79.92/MG for P-removal, 1969 $ (Khan, 1977).

[3]Based on $291/acre-ft-yr calculated for flood control (7 reservoirs) on N. Branch Chicago River, (USDA et al., 1976).

[4]Based on dollar cost (note 3) and energy intensity of 0.0796 MBTU/$ for new construction-public utility (Bullard and Herendeen, 1975).

a very productive ecosystem.

2. Inflows of water to the swamp were primarily from throughfall and runoff-with some contribution due to groundwater. This led to the relatively low ionic strength of the swamp water and a much different character than the adjacent river.

3. Floating vegetation such as duckweed can significantly affect both the productivity and evapotranspiration of these swamps. When swamp water levels are raised, the system selects for aquatic productivity in lieu of tree productivity.

4. Because the swamp had high levels of nutrients imported by the flooding river, low levels of dissolved ions, and reduced conditions in the water, it exports more phosphorus, less sulfates and nitrates and similar levels of major cations as temperate angiosperm-deciduous forests.

5. Flooding can deposit significant amounts of sediment in the alluvial swamp, slowly filling it in. The 8-year flood during this study contributed 0.06 cm of nutrient-rich sediments to the swamp.

6. The frequency and magnitude of flooding has a positive influence on cypress growth, indicating the dependence of one ecosystem on the behavior of another. Man-induced alteration of the flooding frequency of the river would ultimately have an impact on the integrity of the alluvial swamp.

7. The swamp has considerable value to man when the costs of technological alternatives to perform similar functions of flood control and phosphorus removal.

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The Influence of Bird Rookeries on Nutrient Cycling and Organic Matter Production in the Shark River, Florida Everglades[1]

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Abstract.--Nesting birds play a major role in nutrient and organic matter cycling in the headwaters of the Shark River in the Everglades. During the dry season, nesting birds act as upstream vectors of phosphorus and ammonia which stimulates phytoplankton production. This increased production reduces P, NH_4, and dissolved Si along a downstream gradient. Phytoplankton production decreases along this gradient, while Si concentrations rise. Phytoplankton are a major source of particulate carbon during the dry season. The implications of shifts of rookeries from such headwaters to areas north of the Everglades are discussed.

INTRODUCTION

Rivers and estuaries draining the Florida Everglades are characterized by dark brown waters containing relatively high concentrations of dissolved organic carbon and particulate organic carbon (Dreyer 1973). The particulate organic detritus, derived primarily from the decomposition of mangrove (Rizophora mangle) leaves (Heald 1969), has been demonstrated to be an important energy source for consumer communities in this highly productive estuarine environment (Odum 1969; Odum and Heald 1972). Microscopic examination of suspended particles in tidal waters from the lower North River estuary revealed that 35 to 60 percent of the total suspended load is of mangrove origin (Odum and Heald 1975).

In the course of studies on the role of particulate organic detritus as a trasnport mechanism for trace metals (Lindberg and Harriss 1974), we discovered areas in the headwaters of the Shark River estuary characterized by a strongly pulsed, seasonal phytoplankton cycle. During periods of high primary production, phytoplankton may replace mangrove detritus as the primary source of particulate organic carbon in the upper Shark River estuary. This paper presents evidence documenting the origin of and seasonal variations in nutrients, primary production, and particulate organic carbon in headwater areas of the Everglades estuaries.

DESCRIPTION OF THE STUDY AREA

The study area was the complex Shark River estuary system located in the western section of Everglades National Park. Sampling stations were established over the salinity gradient from the headwaters of the Shark River to Ponce de Leon Bay (36 km) along the Little Shark River, Tarpon Bay, Avocado Branch, and Rookery Branch (fig. 1). The Shark River channel is

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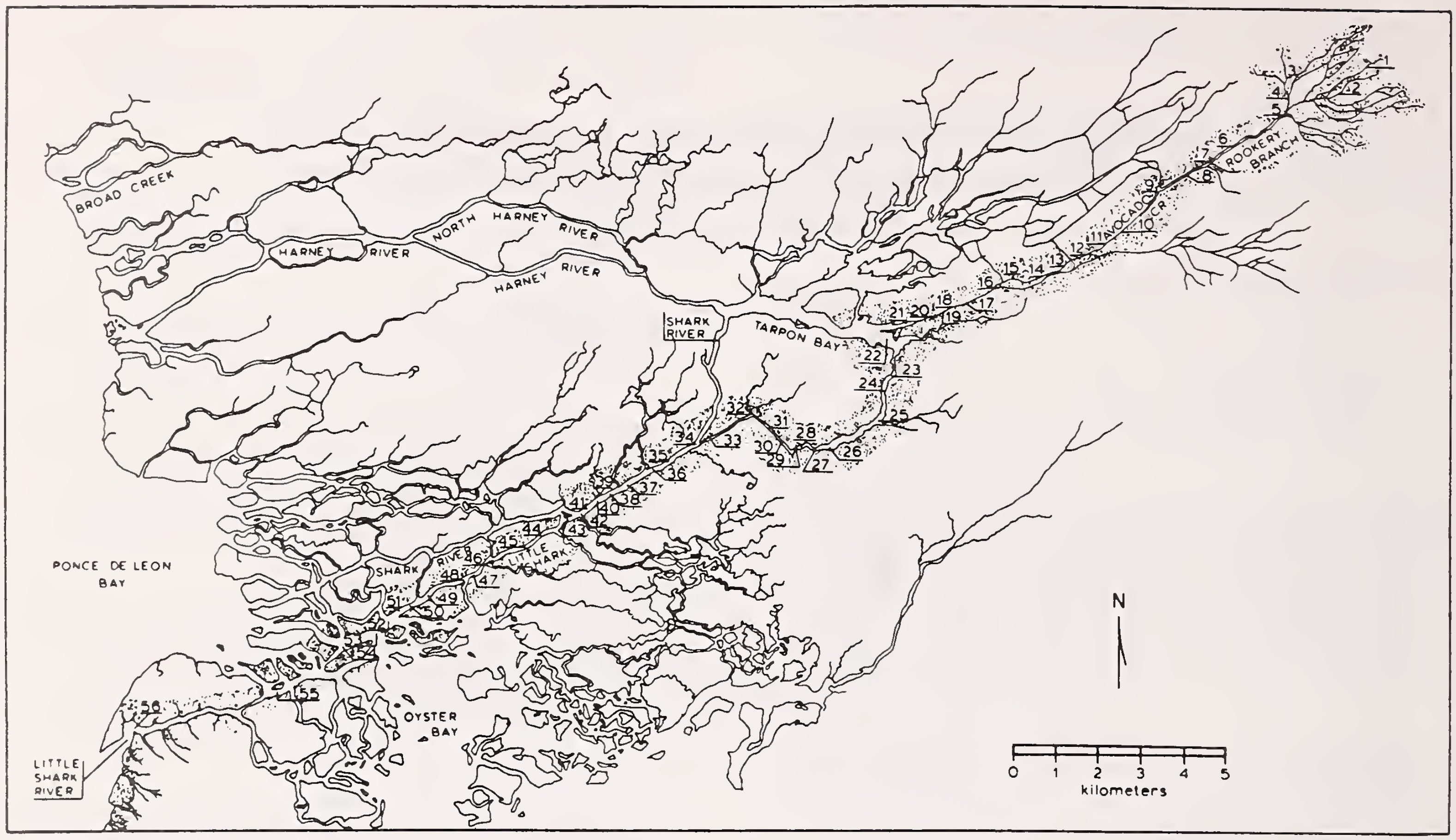

Figure 1.--Map of the study area showing sampling station locations. Stations were determined by the salinity gradient.

lined along its entire length by a red mangrove (Rizophora mangle) forest (fig. 2) with some fresh water species (willows, etc.) intermixed with mangroves towards the headwaters. The mangrove forest is extensive at the mouth of the river but is confined to a narrow strip along the channel(s) at the headwaters; an extensive saw-grass (Cladium jamaicense) marsh grades rather abruptly into this forested strip. The headwaters (Rookery Branch) supports an extensive, mixed breeding colony of herons, egrets, and ibises from about December to April each year. Bird populations in the Shark River rookery ranged from approximately 7,700 to 25,000 individuals according to 1975 field studies by the National Park Service (unpublished data). The extensive bird populations deposit large quantities of fecal material in the roost area both on the mangroves and directly in the water. This fecal material resulted in 5-fold increases in both ammonium-nitrogen and phosphate-phosphorus in roost areas studies by Onuff et al. (1977).

Figure 2.--View of the mangrove forest along the Shark River, Florida Everglades.

Rainfall varies considerably from year to year but is highly seasonal with over half of the 127-152 cm per year occurring in the four months of June through August (Kahl 1964). This seasonal rainfall coupled with a high evapotranspiration rate of about 80% per year (Kahl 1964) results in low flow or stagnant conditions in tidal rivers in this region (including the Shark River) during dry months

and especially in March and April at the end of the dry season.

METHODS

Samples were collected on two consecutive days on three cruises aboard Florida State University's research vessel, R/V TURSIOPS, in March, 1974, August, 1974, and March, 1975 at stations spaced over the salinity gradient (fig. 1). The R/V TURSIOPS served as a base, and all sampling was done using a small boat and outboard motor. During low flow (March, 1974 and 1975), the salinity gradient extended completely to the headwaters, with the headwaters having a salinity of about 2 $^{o}/oo$ (parts per thousand). Salinity increased rapdily to more than 15 $^{o}/oo$ by station 22 (fig. 1). During the wet season (August, 1974) freshwater (less than 1 $^{o}/oo$) extended all the way down to Tarpon Bay (15 km) or station 22 (fig. 1); water less than 5 $^{o}/oo$ extended all the way to station 37 (fig. 1).

At each station, salinity was determined with a Beckman salinometer (precision ± 0.5 $^{o}/oo$). These salinity readings were checked at some stations with a calibrated refractometer. A model 401 Orion pH meter or a Leeds and Northrup Model 7417 pH meter was used to determine pH. Alkalinity was determined by titration with N/50 sulfuric acid to a Brom cresol green-methyl red indicator end point. Water samples were collected from just below the surface in hydrochloric acid washed/distilled water-rinsed polethylene bottles. These samples were immediately preserved with 40 mg/ℓ $HgCl_2$ and placed on ice until return to the R/V TURSIOPS. On board ship, samples for dissolved nutrients were filtered through prewashed 0.45 μ millipore filters within 8 hours of collection. These samples were stored at 4°C until analyzed.

Radiocarbon (^{14}C) uptake by phytoplankton was determined at six sites on each day in August, 1974 and March, 1975. Samples of water were collected from 10 cm below the surface at the 6 sites in 20 ℓ polyethylene containers. These samples were kept at ambient temperature by wrapping them with towels soaked in river water and by shading from the sun. These 20 ℓ containers were returned to the R/V TURSIOPS, were shaken, and (300 mℓ) subsamples were taken for ^{14}C incubation (2 light and 1 dark bottle) for each station. Samples from all 6 stations were incubated under natural light conditions (sunny to partly cloudy) in an open plexiglas container on deck for 2-4 hours; water in the incubation box was kept at ambient sea water temperature by continually flushing sea water through it. Incubation was terminated by injection of buffered formalin.

Phytoplankton samples were collected in 3 ℓ bottles at each ^{14}C station. They were preserved immediately with Lugol's solution (August, 1974) or with 2% buffered formalin (March, 1975).

ATP was also determined in August, 1974 at ^{14}C stations and at every nutrient station in March, 1975. ATP determinations were made using the method of Karl and LaRock (1975) modified for water samples.

Dissolved (DOC) and particulate (POC) organic carbon were determined using the method of Menzel and Vaccaro (1964) on an Oceanography International Total Carbon Analyzer. Samples for DOC and POC were collected at each sampling station and were placed on ice until return to the R/V TURSIOPS. Replicated samples were filtered through precombusted Gelman Type A glass fiber filters (pore size 1-3 μ), reagents were added, and ampules were sealed within 8 hours of collection. The ampules were autoclaved and analyzed upon return from the cruise.

Dissolved nutrients were analyzed using standard auto-analyzer techniques on a Technicon II AutoAnalyzer System. Total and total dissolved phosphorus were analyzed using the persulfate digestion method, Section 223C-III, Standard Methods (APHA 1971).

RESULTS AND DISCUSSION

Nutrient concentrations in the upper Shark River estuary for March, 1974 and March, 1975 (the periods representative of low flow) showed remarkably similar trends for most nutrients. In both years, molybdate reactive phosphorus (PO_4-P) was very high in the headwaters (up to 117 μg/ℓ) but dropped off rapidly downstream of the rookery area, to a level of less than 5 μg/ℓ at a salinity of 5 to 7.5 $^{o}/oo$ (parts per thousand), followed by a slight rise to 10-12 μg/ℓ in undiluted sea water (fig. 3). Total and total dissolved phosphorus followed this same trend with total P decreasing rapidly from 290-300 μg/ℓ to 20-30 μg/ℓ then increasing to 30-50 μg/ℓ in undiluted sea water.

The molybdate reactive silicon concentrations were relatively high initially, decreasing to minimum values at about 2-5 $^{o}/oo$, then increasing to a level slightly greater than 2 mg/ℓ at a salinity of about 7.5 $^{o}/oo$ (fig. 4). From this point on, the dissolved silicon exhibited linear dilution with sea water with

changes in slope of the dilution line corresponding to changes in hydrologic regime in the Shark River.

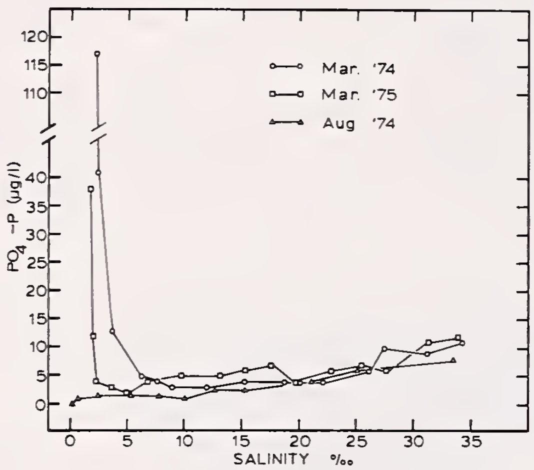

Figure 3.--Variation in molybdate reactive phosphorus (PO_4-P) as a function of salinity in the Shark River.

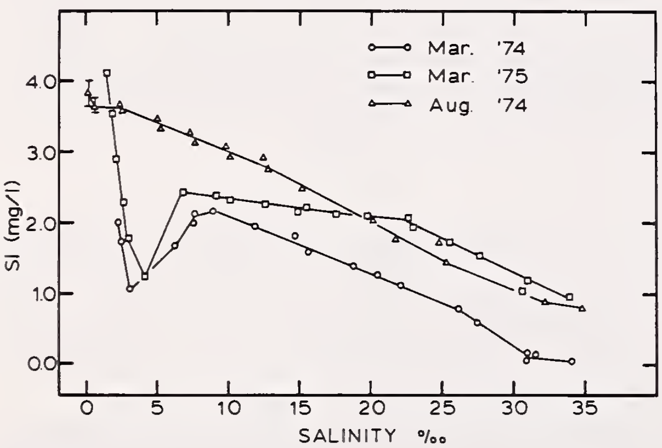

Figure 4.--Variation in molybdate reactive silicon as a function of salinity in the Shark River.

Ammonia-nitrogen (fig. 5) and nitrite-nitrogen showed a similar trend in March, 1975 (NO_2-N decreased rapidly from 230 µg/ℓ to 6-10 µg/ℓ) but were highly variable with no apparent trend in March, 1974. March, 1975 was a wetter period with higher discharge and the salinity gradient was not as sharply defined as it was in March, 1974. This decreased flushing due to lower flows probably accounts for the between year differences. Also, more stagnant conditions decrease oxygenation of the water column, and could have increased the amount of ammonium-nitrogen released from the anaerobic bottom sediments. There was no apparent trend in nitrate-nitrogen concentrations in either year; concentrations ranged from 16 to 88 µg N/ℓ in 1975 and from 15 to 79 µg N/ℓ in 1974.

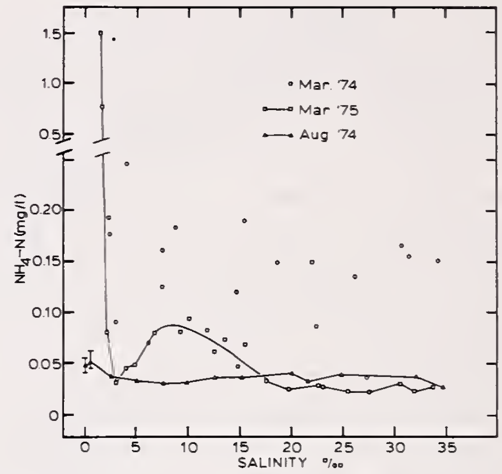

Figure 5.--Variation in dissolved ammonium-nitrogen as a function of salinity in the Shark River.

The dissolved organic carbon (DOC) followed a trend similar to PO_4-P with relatively high levels in the headwaters and lower levels downstream (fig. 6). DOC was expected to dilute out with increasing salinity (Dreyer 1973); however, dilution from the headwaters to about 7.5 ‰ was greater than predicted on the basis of straight dilution (fig. 6). From about 7.5 ‰ to 35 ‰, dilution was linear. Particulate organic carbon (POC) is much more variable (fig. 7) and is affected by the scouring effect of tides. However, there was also an obvious drop from 7.25 mg C/ℓ to variable levels of 1.4 to 0.4 mg C/ℓ POC at a salinity of about 5 ‰ in March, 1975.

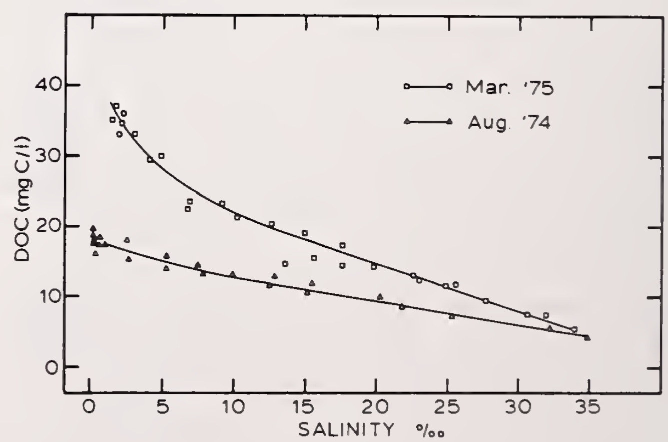

Figure 6.--Variation in dissolved organic carbon as a function of salinity in the Shark River.

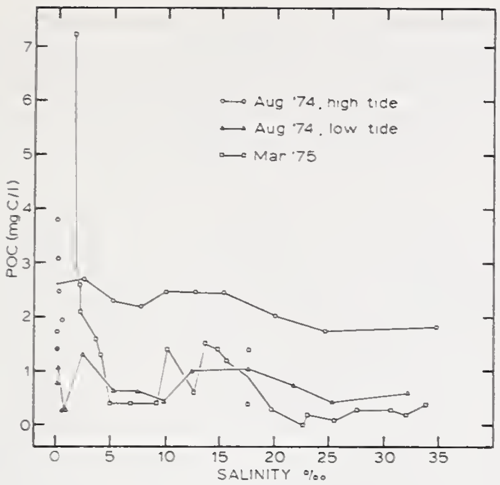

Figure 7.--Variation in particulate organic carbon as a function of salinity in the Shark River.

The trends in dissolved nutrients were completely changed under high flow conditions (August, 1974). At the seven headwaters stations (salinity less than 0.5 ‰) PO_4-P was below limits of detection (1 μg/ℓ); as salinity increased, PO_4-P concentrations increased to levels of 6-9 μg/ℓ (fig. 3). Dissolved silicon concentrations varied from 3.66 to 4.02 mg Si/ℓ in the freshwater part of the stream and diluted out with increasing salinity (fig. 4). There was no clear-cut trend with NH_4-N (fig. 5) or with NO_3-N or NO_2-N (NO_3-N ranged from 3 to 91 μg N/ℓ and NO_2-N ranged from 2 to 15 μg N/ℓ) but both DOC and POC tended to dilute out with increasing salinity (fig. 6 and 7).

After our initial observations of trends in nutrients in March, 1974, we hypothesized that phosphorus and nitrogen inputs from fecal droppings from nesting birds were acting as a nutrient pump in the Shark River and that this increased nutrient loading was driving a seasonal bloom of phytoplankton dominated by diatoms. Thus, the diatom bloom resulted in the depression of dissolved silicon concentratons. Edwards (1974) showed that diatom blooms depleted silicon concentrations in rivers in England. To test this hypothesis, we ran ^{14}C productivity, ATP determinations, and phytoplankton counts in addition to nutrients in August, 1974 and March, 1975. ATP, while controversial, may indicate increased microbial and/or plankton biomass; it was high in the headwaters and decreased downstream to relatively constant levels from about 5 to 7.5 ‰ (fig. 8). Also ^{14}C productivity followed the same trend (fig. 9). In August, 1974, both ATP and ^{14}C productivity was low at the freshwater stations and increased somewhat with increasing salinity, a reversed trend from the dry season. Phytoplankton counts also followed the same trend with more than 8 times as many cells per liter at the headwaters station than at the sea water station (Table 1) in March, 1975. The ratio of diatom to non-diatom phytoplankton also decreased downstream as expected from the chemical data in March, 1975; diatoms were significant components at all stations in August, 1974 (Table 1). Thus, the hypothesis that fecal inputs from the bird rookery are acting as a nutrient pump which drives a seasonal, diatom dominated increase in phytoplankton biomass seems to be valid.

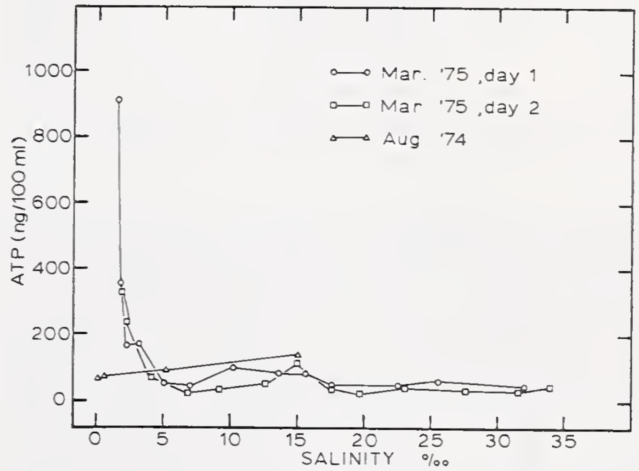

Figure 8.--Variation in total ATP activity as a function of salinity in the Shark River.

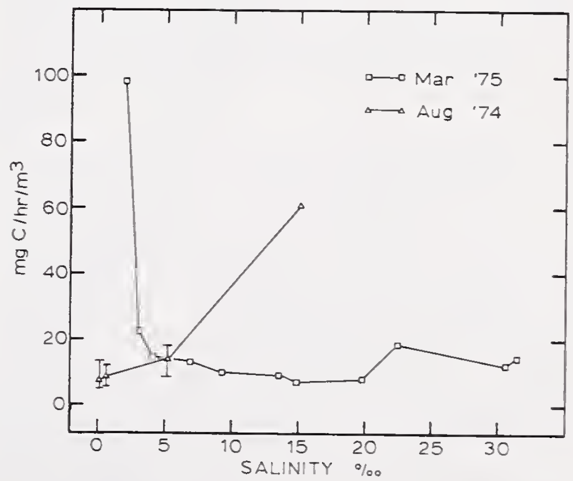

Figure 9.--Variation in total ^{14}C carbon fixation as a function of salinity in the Shark River.

An alternate hypothesis is that the increased inputs of nutrients coming into the headwaters during the dry season are derived from input from the surrounding sawgrass areas of the Everglades. However, Steward and Ornes (1975) report low nutrient values ranging from 29 to 213 μg P/ℓ for total P in water in sawgrass areas of the Everglades. Correlations

Table 1.--Phytoplankton data for the Shark River Estuary in Everglades National Park, August, 1974 and March, 1975

August, 1974			March, 1975		
Salinity $^o/oo$	Total cells/liter	Diatoms/ Non-diatoms	Salinity $^o/oo$	Total cells/liter	Diatoms/ Non-diatoms
0.0	1.20×10^6	1.70	1.8	12.3×10^6	1.14
0.0	0.75×10^6	0.73	2.1	7.0×10^6	1.41
0.1	1.04×10^6	0.73	4.0	5.1×10^6	1.01
0.4	1.25×10^6	0.90	9.2	1.5×10^6	0.65
5.1	0.94×10^6	1.18	14.8	1.8×10^6	0.78
15.0	1.16×10^6	1.30	19.7	1.5×10^6	0.80

between rainfall and concentration of total P in water in sawgrass stands were statistically insignificant in their study. Our values for total P in the Shark River headwaters range from 250 to 299 μg P/ℓ in March and from 10 to 26 μg P/ℓ in August. Surface runoff from the sawgrass plains is negligible during the dry season. Thus, there is no basis to support the hypothesis that runoff from sawgrass contributes nutrients to the Shark River estuary during the dry season.

The results of this study suggest a rather unique mechanism for estuarine nutrient cycling. Phytoplankton production in the headwaters of the Shark River estuary is very low and is probably limited by the low dissolved phosphorus concentrations of less than one μg/ℓ during the period of high rainfall and runoff (June-November) and perhaps, to a lesser extent, by lower inorganic nitrogen concentrations. The primary source of particulate organic matter for the aquatic consumer community during the wet season is mangrove detritus (Odum and Heald 1972). In contrast, during the dry season (December-May) the development of an extensive bird rookery in the mangrove forest adjacent to the headwaters of the Shark Estuary increases dissolved phosphorus concentrations up to 115 times above wet season levels, increases ammonium and nitrite nitrogen concentrations, and correlates with an approximately 100-fold increase in measured rates of primary production, an 8-fold increase in cell numbers, and increased ATP concentrations. During the dry season, phytoplankton become much more important as a source of particulate organic matter in the headwaters of the Shark River estuary. At the same time, the supply of mangrove detritus to the estuary from the adjacent forest is minimized during the dry season by reduced rainfall and runoff.

Several alternative hypotheses are possible including increased leaching of tannins or other allelochemicals during the wet season leading to inhibition of phytoplankton; increased turbidity due to increased flow during the wet season leading to reduced light availability, etc. The nutrient limitation hypothesis is the most likely explanation in our opinion but the other hypotheses cannot be excluded at this time. The fact that the major nutrients were depleted by increased numbers and production of phytoplankton and the recovery of Si concentrations downstream of the zone of high plankton production certainly suggest that the nutrient limitation hypothesis is the correct one.

The bird populations which nest in the headwater areas of the Shark River feed in the marine environment and act as a vector for the movement of nutrients from the sea to the estuary, often flying as much as 40 km away to feed (Kahl 1964). The birds input energy into the nutrient cycle both through transport and chemical transformation. The magnitude of these inputs is illustrated by studies on nearby wood stork rookeries (Kahl 1964). He estimated a 6000 nest colony would consume 1.2×10^6 Kg of food (live weight) per season with about one-fifth of this or 240 metric tons being excreted in the nesting area. Thus, the 7,700 to 25,000 individual egrets, ibises, and herons observed in the rookery by the National Park Service represent an input of from 100 to 300 metric tons of excreta, a very significant input of both energy and nutrients. The effect of this input on the mangroves and their herbivores has been well documented recently (Onuf et al. 1977). The highly enriched nutrient content of the water under these rookery areas (Onuf et al. 1977) can also dramatically alter the biotic responses of streams draining these areas as is documented in this paper.

Other well documented examples of animals as vectors for movement of nutrients from the sea to estuarine and stream environments include salmon migrations (Krokhin 1975) and birds active around brackish water rockpools (Ganning and Wulff 1969).

During recent years, bird count surveys by the National Park Service biologists (unpublished data) and qualitative observations of bird watchers indicate a major shift in the winter nesting areas of Everglades birds from the headwaters of the Shark River to water conservation areas located immediately to the north of Everglades National Park. This shift in nesting areas could result in reduced primary production in the Shark River estuary (oligotrophication) and other headwater nesting areas and increased primary production and eutrophication in the water conservation areas of the Central and Southern Florida Flood Control District. Such shifts could result in major impacts on both systems and should be considered in management plans for these systems.

ACKNOWLEDGMENTS

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Beaver Pond Ecosystems and Their Relationships to Multi-Use Natural Resource Management[1]

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Kerry P. Reese, and David K. Woodward[2]

Abstract.--Thousands of hectares of land have been impounded by beavers in the southeastern United States. Significant economic losses to agribusiness and forest production have been reported. However, beaver impoundments are valuable components of many regional riparian ecosystems and provide numerous opportunities for multi-use management programs. As a renewable fur resource, beaver populations should be regulated through an annual sustained harvest. Beaver impoundments are important wetland habitats and have higher avian diversity values than adjacent upland areas. They can be effectively managed for waterfowl hunting and with the increased importance of non-consumptive utilization of wildlife resources, they provide numerous opportunities for development of natural resource education programs.

INTRODUCTION

Riparian ecosystems are wetlands habitats usually occurring as ecotones between aquatic and upland areas. In the southeastern United States riparian ecosystems are most commonly recognized as bottomland hardwoods or floodplain forests. Throughout this region thousands of hectares (ha) of land associated with riparian habitats have been drained and changed to alternative land-use practices (Niering 1966, Landin 1978). Today, most remaining floodplain wetlands in the interior southeast are areas not economically feasible to develop. Within this region, however, beaver (Castor canadensis) populations have increased dramatically in recent years (Arner et al. 1969, Beshears 1967, Godbee and Price 1975, Hill 1976, Woodward et al. 1976, Arner and Dubose 1978 and Kinard 1978), and thousands of hectares of land associated with regional riparian ecosystems have been impounded. Although significant negative economic impacts have been recognized (Woodward et al. 1976), these impoundments have created important wetland habitats for wildlife resources (Reese and Hair 1976).

The purpose of this paper is to (a) provide a brief report on the status of the beaver resource in the southeastern United States, (b) define the types of wetland habitats of beaver ponds associated with regional riparian ecosystems, and (c) describe the importance of these habitats to wildlife resources. This paper summarizes data from a series of research projects dealing with beaver pond ecosystems in South Carolina. It was supported by the South Carolina Agricultural Experiment Station, Clemson, S. C. For details not included in this report refer to Reese (1976), Reese and Hair (1976), Woodward et al. (1976), Hepp (1977), Hepp and Hair (1977), Luckett (1977) and Woodward (1977).

STATUS OF THE BEAVER RESOURCE IN THE SOUTHEAST

Prior to 1850 beavers were natural components of most watersheds in the southeastern United States (Hill 1976). However, during the period from 1850 to 1900, they were essentially eliminated from this region by the effects of over-harvest and loss of habitat from the

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clearing of land for agricultural production. In 1929, for example, a statewide inventory of beaver impoundments in Alabama located only 41 dams (Barkalow 1949). By the early 1900's beavers were protected by law and by the late 1940's restocking programs had been undertaken by federal and state wildlife agencies.

In recent years beaver populations have increased rapidly throughout the region. Concurrently reports of substantial damage to land resources through nuisance flooding and destruction of crops, pastures and timberlands have resulted. For example, Hill (1976) reported a minimum of 161,877 ha of floodplain timberlands were inundated by beavers in 10 southeastern states with damages estimated in excess of 7 million dollars. Surface areas flooded by beavers in the last 10 years have increased 128 percent in Georgia (Godbee and Price 1975) and 300 percent in Mississippi (Arner and Dubose 1978). Furthermore, the distribution of beavers in South Carolina has increased from 12 to 28 counties since 1966 with a minimum of 7,000 ha of land inundated and annual damages in excess of $225,000 (Woodward et al. 1976).

In areas where beaver activities have exceeded economic thresholds, control programs are warranted. However, as demonstrated herein, beaver pond ecosystems are extremely valuable to wildlife resources and long-term management objectives that emphasize multiple-use concepts should be developed.

CLASSIFICATION OF BEAVER POND HABITATS

Two general categories of beaver impoundments are found in the southeastern United States: (a) "stream channel" ponds, and (b) "floodplain" ponds (Pullen 1971). Stream channel beaver ponds are usually long, narrow and less than 1 hectare in size. Floodplain ponds characteristically bisect bottomland areas and, although relatively shallow (less than a meter deep), can inundate many hectares of land. Depending on the local topography, both types of impoundments may occur within the colony site of a single family group. Stream channel dams frequently lengthen into floodplain dams as colony size and time of site occupancy increase. A complex of beaver ponds within a localized area having different physical and biological characteristics results.

A wetlands classification system for beaver pond habitats in the piedmont region of South Carolina was developed in conjunction with a wood duck (common names for avian species according to A.O.U. 1957, 1973) brood habitat selection study (Hepp 1977). This system was based on distribution and abundance of dominant vegetation. A "dominant" was defined as an uppermost layer of vegetation having an aerial coverage greater than 30 percent (Cowardin et al. 1976). A wetland area comprised of less than 30 percent plant cover was referred to as a "non-vegetated" wetland. The following is a brief description of wetland habitats we defined in conjunction with our studies.

Figure 1.--Deciduous Forest Wetland (1BP) - This wetland was dominated by trees (woody plants which at maturity were 6 m or more in height and usually with a single trunk), such as water oak (Quercus nigra), sweet gum (Liquidambar styraciflua), and red maple (Acer rubrum); it occurred most often on the edges of the beaver ponds.

Figure 2.--Deciduous Shrub Wetland (2BP) - This wetland was dominated by shrubs (woody plants less than 6 m tall with several erect stems), such as tag alder (Alnus serrulata), buttonbush (Cephalanthus occidentalis), and privet

(Ligustrum sinese). Standing dead vegetation was also included in the shrub category.

Figure 3.--Emergent Vegetation Wetland (3BP)- This wetland was dominated by a mixture of emergent aquatic vegetation such as asiatic dayflower (Aneilema keisak), rice cutgrass (Leersia oryzoides), and soft rush (Juncus effusus). This type predominated in silted sections and along the margins of older beaver ponds.

Figure 4.--Bur-reed Wetland (4BP) - This wetland was dominated by bur-reed (Sparganium americanum). This type comprised a small portion of the study area.

Figure 5.--Rice Cutgrass Wetland (5BP)- This wetland was dominated by rice cutgrass. It occurred over much of the study area, primarily where water was shallow and still.

Figure 6.--Submergent Vegetation Wetland (6BP) - This wetland was dominated by submergent vegetation such as pondweed (Potamogeton confervoides). It occurred mainly in shallow sections of the beaver ponds.

Figure 7.--Non-vegetated wetland (7BP) - These were all permanently flooded non-vegetated substrates (see above). This wetland type usually was associated with deeper sections of the ponds and comprised a major portion of the study area.

Two other wetland types present on the study area were temporary wetlands (TW) and riverine wetlands (R). Temporary wetlands were areas in which water covered the land surface for less than half the year. Riverine wetlands were directly influenced by the flow of water along a stream channel. Vegetative communities used to classify beaver ponds were also utilized for these non-beaver pond wetlands (i.e. Deciduous Forested (1), Deciduous Shrub (2), etc.).

WILDLIFE HABITAT RELATIONSHIPS

Avian Species Diversity

Several factors are important in the determination of faunal diversity of biotic communities. As structural heterogeneity of a habitat increases, the number of microhabitats potentially available also increases (Willson 1974). In general, this corresponds to an increase in the number of species in a given area (Rogers 1967, Karr and Roth 1971, Emlen 1973, Gauthreaux 1978, inter alia). Distribution, volume, density, and vertical stratification of vegetation, as expressed by indices of foliage height diversity, total percent cover and vegetation strata diversity, are important in determining avian species diversity of terrestrial habitats (MacArthur 1964, Karr 1968, Recher 1969, Karr and Roth 1971, Willson 1974, Rov 1975). However, these indices alone are not adequate to predict avian species diversity in certain types of habitats, i.e., some coniferous forests (Kilgore 1971, Balda 1969, 1975), tropical forests (Lovejoy 1971) and desert scrub (Tomoff 1974) communities. Other features of the habitat such as open water, swamps, rock outcroppings, cavity trees, and unique plant life forms may serve as additional structural components that influence avian species diversity values (Dwyer 1972, Tomoff 1974, Balda 1975). Karr (1968) and Ferguson et al. (1975) report the presence of water added structural complexity to the habitat and thereby increased the abundance of the local avifauna. Research on avian communities associated with riparian habitats in the southwestern United States supports further the importance of aquatic areas to wildlife resources (i.e. Anderson and Ohmart 1977, Hubbard 1977, Stevens et al. 1977 and Wauer 1977).

In South Carolina a total of 104 species of birds was recorded at 15 census sites (5 beaver pond, 5 upland hardwood, 5 pine) on a 36 ha study area. Of this total, 25 species were categorized as residents, 18 as breeding migrants, 18 as wintering migrants, 29 as transients, and 14 as irregular visitors. (For further details see Reese 1976). Regardless of season, diversity values (H'= Shannon and Weaver Diversity Index, S= Number of Species) were significantly higher ($p<.05$) at the beaver ponds than at adjacent hardwood and pine areas (Table 1). The avifauna of the hardwood areas was more diverse (H' and S) than the pine habitat, but the only statistically significant differences were during winter (H' and S) and spring (S). The equitability component (J) was significantly different among habitat types only during the fall season. Equitability for beaver pond avifauna was significantly lower than the corresponding value for hardwood habitat. This was the result of high numbers of wood ducks at the pond sites during fall migration (23 percent of the total density of 46 species of birds at the pond sites during the fall). The beaver pond habitat consistently had the highest number of individuals (N) in each season (Table 1). Pines were lowest in numbers of individuals, but were not significantly different from hardwoods.

While water itself attracted aquatic and semi-aquatic species to beaver ponds, features such as dead trees, fallen logs and abundant seed crops of aquatic plants also attracted non-aquatic species of birds (Table 2). The mean number of individuals of non-aquatic birds occurring at the pond sites was from 49 percent (winter) to 103 percent (spring) greater than at the 10 terrestrial sites. Standing dead trees suitable for feeding and nesting sites for woodpeckers were probably the major factor contributing to the 296 to 445 percent increase in the density of picids throughout the year (Table 3). Carolina chickadees and tufted titmice were also attracted to dead trees, and

these species increased (83 to 167 percent) at the beaver pond sites (Table 3). Both common grackles and brown-headed cowbirds foraged by walking along fallen logs floating in the water. Chimney swifts and Eastern phoebes also utilized the pond sites as feeding areas (Tables 2 and 3).

The intensity of utilization of the ponds by certain bird groups changed with season. During the summer and winter, troglodytids (winter wren and Carolina wren) and insectivorous bark gleaners (kinglets and brown creepers) were observed more frequently at beaver ponds than terrestrial sites but, during spring both groups preferred terrestrial habitats (Table 3). This may reflect a reduction in food resources at the pond sites as a result of heavy utilization by several species of birds during the fall and winter seasons. Guild 244 (following Willson 1974), the insectivorous, middle layer, foliage gleaners (yellow-billed cuckoos, blue-gray gnatcatchers, white-eyed vireos, yellow-rumped warblers, scarlet tanagers) preferred the edges of the beaver ponds during summer and spring, but had a greater density at the terrestrial sites during the winter. However, the yellow-rumped warbler was the only species of this guild present during the winter, and as reported by Parnell (1969), preferred the upland hardwood and pine habitats. Omnivorous foliage gleaners, especially blue jays, foraged extensively throughout the heavy cover at the edges of the beaver ponds.

Ground-dwelling species (e.g. wood thrushes and rufous-sided towhees) preferred terrestrial sites during summer (Table 2). Hermit thrushes also favored terrestrial sites during fall and winter (Table 2). However, towhees, brown thrashers and white-throated sparrows preferred beaver ponds during non-breeding seasons (Table 3).

The suitable habitat (not covered by water) for ground-dwelling species of birds was limited at the beaver ponds. Territorial behavior during the summer period probably reduced the density of ground-dwelling species at the pond sites (Tramer 1969, Reese and Hair 1976).

Table 1.--Seasonal values (means ± one standard deviation) of bird species diversity (H'), species richness (S), equitability (J) and number of individuals (N) for three habitat types in the piedmont region of South Carolina.

Habitat Type	Season1/	H'	S	J	N
Beaver Pond	S	2.18±.30	11.7±3.5	.906±.042	26.7±10.2
	F	2.06±.58	12.2±3.4	.838±.111	42.9±31.6
	W	2.08±.41	11.4±4.2	.876±.075	35.5±20.7
	SP	2.45±.36	15.9±4.6	.898±.050	40.5±17.2
	Annual	2.19±.18	12.8±2.1	.880±.030	36.4± 7.2
Hardwood	S	1.49±.30	5.6±2.5	.920±.042	11.0± 4.6
	F	1.62±.58	6.9±3.4	.915±.064	16.4±12.2
	W	1.58±.43	6.9±3.1	.863±.120	19.2±15.0
	SP	1.90±.33	8.6±2.8	.916±.042	18.4± 9.6
	Annual	1.65±.18	7.0±1.2	.904±.027	16.2± 3.7
Pine	S	1.57±.34	6.0±1.9	.898±.064	11.9± 4.8
	F	1.47±.47	6.1±2.6	.881±.064	15.2±10.7
	W	1.25±.48	5.0±2.3	.841±.124	15.8±11.1
	SP	1.62±.40	6.3±2.2	.916±.053	12.3± 6.9
	Annual	1.48±.16	5.8±0.6	.884±.032	13.8± 2.0

1/ Seasons: S = summer, F = fall, W = winter, SP = spring.

Table 2.--Comparisons of the mean numbers of individuals of selected species of birds that occurred at both the beaver pond (BP) and terrestrial habitats (T) in the piedmont region of South Carolina. Birds listed occurred at 6 or more census sites during each season.

	Summer		Fall		Winter		Spring	
	BP	T	BP	T	BP	T	BP	T
Yellow-billed Cuckoo	5	3						
Chimney Swift	9	1					3	1
Common Flicker	2	1	9	2	2	1		
Red-bellied Woodpecker	10	2	4	1	17	2	8	1
Downy Woodpecker	6	1	4	1	4	2	3	1
Blue Jay	8	10	35	11	14	7	8	8
Carolina Chickadee	10	5	12	8	20	9	12	3
Tufted Titmouse	1	1	10	2			4	3
Carolina Wren	17	14	9	10	19	8	4	6
Wood Thrush	1	1						2
White-eyed Vireo	1	1						
Red-eyed Vireo	1	2					2	2
Common Grackle	8	1						
Cardinal	12	10	4	5	3	4	10	6
Rufous-sided Towhee	1	6	4	2	11	4	13	6
Pileated Woodpecker			4	1	1	1	2	1
Winter Wren			1	1	5	3		
Brown Thrasher			4	1			2	1
Robin			6	5	3	8		
Hermit Thrush				2	1	2		
Golden-crowned Kinglet			12	7	31	29		
Ruby-crowned Kinglet			1	3	16	19	4	6
Pine Warbler				4	2	8		4
Yellow-bellied Sapsucker					3	1	2	1
Brown Creeper					2	1		
Yellow-rumped Warbler					2	6	4	6
Purple Finch					1	10		
White-throated Sparrow					12	5	8	1
Eastern Phoebe							1	1
Blue-gray Gnatcatcher							4	1
Brown-headed Cowbird							2	1
Scarlet Tanager							2	1
Mean total number of individuals	92	59	119	66	169	130	98	63

Table 3.--Seasonal percent differences (PD) in density of groups of ecologically similar birds observed at beaver pond and terrestrial habitats in South Carolina.

Similar species group[1/]	PD[2/]			
	Summer	Autumn	Winter	Spring
Picidae (all woodpeckers)	445	296	329	359
Icteridae (common grackles and brown-headed cowbirds)	1900			567
Troglodytidae (wrens)	21	0	129	-33
Resident, cavity nesting insectivores (Carolina chickadees and tufted titmice)	83	120	122	167
Ground-dwelling species	-82	208	116	144
Omnivorous foliage gleaners (cardinals, blue jays and robins)	0	114	5	29
Aerial insectivore (chimney swifts)	1025			900
Insectivorous, high canopy, foliage gleaners (red-eyed vireos, pine warblers)	-35			-67
Insectivorous, middle layer, foliage gleaners (cuckoos, gnatcatchers, white-eyed vireos, tanagers)	46		-67	43
Wintering, insectivorous bark gleaners (kinglets, creepers)		26	1	-38
High canopy seedeater (purple finches)			-87	
Sallying insectivore (Eastern phoebes)				67

[1/] species included are those from Table 2.

[2/] Positive/negative values indicate increased/decreased comparative densities between beaver ponds and terrestrial habitats.

With the decline in territoriality towards the end of the summer, density of ground-dwelling species increased at the pond sites by over 200 percent (Table 3). These species were primarily seed and fruit eaters during the non-breeding seasons, and probably exploited the locally abundant seed crops at the pond's edges in the manner reported by Zimmerman and Tatschl (1975). Dwyer (1972) also noted that "swamps" significantly increased the distribution and abundance of seed-eating species of birds.

The insectivorous, high canopy, foliage gleaners, (e.g. red-eyed vireos and pine warblers), definitely preferred the terrestrial sites (Tables 2 and 3). The vireos tended to prefer the hardwood sites, while the pine warblers were strongly associated with pine forests (Parnell 1969). Both of these species required well-developed canopies (Anderson and Shugart 1974) not associated with beaver ponds, but typical of pine and hardwood forests.

Over a period of 1 year, raptors were sighted 28 times at the three beaver ponds, while only 8 sightings were recorded at the adjacent terrestrial sites. On several occasions hawks were observed pursuing other birds on the study area. Carr (1940) noted that hawks utilized dead, standing trees in beaver ponds as resting perches. In addition, increased

density of birds, and open areas over water, provided less cover for prey species. Apparently, these were important factors making ponds preferred hunting areas for raptors.

In summary, beaver pond habitats were utilized by the majority of the avian species present on the entire study area. While some groups of species preferred the pond sites on a seasonal basis (e.g. the wrens), the only groups that were negatively affected by changes in vegetation associated with the beaver ponds were high canopy seedeaters and insectivorous, high canopy, foliage gleaners. The research summarized above, and detailed for four additional beaver pond complexes (Reese and Hair 1976), has established objectively that these wetland riparian ecosystems provided excellent habitats throughout the entire annual cycle for a wide variety of game and non-game species of birds.

BEAVER PONDS AND WOOD DUCK HABITAT RELATIONSHIPS

Wood ducks, because of their resident status and rank as the number one species of waterfowl harvested in several states (Benning et al. 1978), are the most important waterfowl resource in the Southeast. As discussed in the following, riparian ecosystems, particularly beaver ponds, provide important roosting,nesting and brood rearing habitats for wood ducks and are a major component in their overall ecology and management.

Roosting

The value of beaver ponds to waterfowl, particularly wood ducks, has been recognized for a long time (Beard 1953 and Speake 1955). Beshears (1955) noted that, with the exception of the Tennessee Valley Authority lakes and the Mobile Bay delta, beaver ponds in Alabama collectively receive greater waterfowl utilization than any other habitats. Speake (1955) compared the waterfowl utilization of 4 aquatic habitats (creeks, small impoundments and beaver ponds) and determined that beaver ponds received greatest use by waterfowl throughout the year. This reflects the importance of beaver ponds in providing roosting, nesting, and brood rearing habitats for regional populations of wood ducks.

A major objective of our research in South Carolina was to determine habitats on the study area utilized by wood ducks for roosting and daytime activities. Wood ducks, because of their seclusive nature, normally are not easily observed or censured. However, during the fall flight activities associated with evening roost sites and daytime nesting/feeding areas (Martin 1959, Hester and Quay 1961, Hein 1966, Taberrer 1971 and Luckett 1977) provided an opportunity to census populations associated with different habitats.

Wood ducks roost in a variety of habitats such as wooded sloughs, swamps, man-made impoundments, seasonally flooded basins, millponds, and beaver ponds. Fallen trees, shrubs and emergent aquatic vegetation associated with beaver ponds provide excellent roosting sites throughout the Southeast United States (e.g. Speake (1955) and Beshears (1974) in Alabama, Almand (1965) in Georgia, Taberrer (1971) in Louisiana, Hester and Dermid (1973) in North Carolina, and Luckett (1977) in South Carolina.

Our flight activity data showed significant correlations ($p<.001$ $r = .94$) in the numbers of wood ducks involved in the evening/morning flight activities associated with the beaver pond complex understudy and a large freshwater swamp located approximately 10 km away. When adjusted for lag times associated with flight time, the numbers of arrivals and/or departures of wood ducks from the respective habitats per unit time were also significantly inter-correlated ($p<.001$, $r = .92$). This provides strong circumstantial evidence (in the absence of known numbers of marked birds) supporting the importance of the beaver pond complex as a major roost site on our study area during the fall season. In addition to the resident population, migrant wood ducks from northern areas also utilized the beaver pond roost in the fall. For further details refer to Luckett (1977).

Nesting

The successful production of waterfowl requires suitable habitats for nesting and brood rearing. Wood ducks are one of the few species of waterfowl that require cavities for nesting (Bellrose 1976a,b,). On our study area the impact of natural cavities on the total productivity of the local wood duck population was minimal (Luckett 1977). A survey of tree cavities on 27 beaver impoundments provided no evidence of usage by nesting wood ducks. Futhermore, potential nesting cavities in standing dead trees within the perimeter of the beaver ponds were available only for a few years before the trees deteriorated and fell into the water.

With the use of artificial nesting structures, our research results agree with other reports in the literature of the importance of beaver ponds as nesting habitats for wood ducks (e.g. Arner 1964, Stanton 1965, Hogdon and Hunt 1966, Nevers 1968, Stewart 1972 and Beshears 1974). For example, in 1974, 74% (17/23) of the nest boxes located on beaver ponds as compared to 11% (3/27) of the boxes on other habitats (freshwater marsh, man-made impoundment)

were utilized for nesting (Luckett 1977).

It is difficult to determine specifically the attributes of beaver ponds that are most important for successful nesting by wood ducks due to the complexity and interrelationships of possible factors. Beard (1953), in a now classic study, discussed 6 physical characteristics of beaver ponds which made them attractive to waterfowl: 1)amount of interspersion created, 2) composition and juxtaposition of the seral stages, 3) depth of water, 4) species and abundance of plant and animal foods present, 5) lack of human disturbance, and 6) suitable nesting cover.

When we examined the general physical characteristics of beaver ponds, some important trends in nest box utilization were apparent. For example, older ponds (i.e., over 6 years)with fewer trees/ha were utilized more than younger ponds. Open nesting habitat apparently increased the potential for contact with next boxes. Nesting wood ducks, for the most part, do not utilize nest boxes placed in habitats of dense vegetation (Bellrose 1955, and Naylor 1960). Other factors were analyzed (e.g. types of vegetation, water depth and size of pond) but, because of interrelationships between key variables, their individual importance to nest box utilization could not be determined.

Brood Rearing

Wood duck broods generally prefer areas with downed timber and shrubs combined with heavy cover created by shrubs and emergent herbaceous vegetation (Webster and McGilvrey 1966, and Ball 1973). However, little quantitative data are available on the actual use of various types of aquatic habitats by wood duck broods throughout the rearing period. Therefore, we initiated a study of brood rearing behavior of wood ducks that nested on beaver ponds in the piedmont region of South Carolina (Hepp 1977). In order to categorize brood habitat use, the wetland classification system discussed previously was devised.

Most hens with broods that were monitored (67 percent) were very mobile and ranged over large areas during the first 24 to 48 hours after leaving the nest (Hepp and Hair 1977). After a "suitable" area was located, the hen and brood usually remained there until the end of rearing (as determined by the dissolution of the hen-brood bond).

Beaver pond habitats were the most heavily utilized of the available wetland areas, particularly when dominated by rice cutgrass, deciduous shrubs, a mixture of emergent aquatic vegetation and/or a combination of these types (Table 4). The combination of a shrub layer and emergent aquatic vegetation appeared to provide most requirements needed for good brood habitat. Shrubs provided cover and security for broods as well as some loafing sites while the underlying layer of herbaceous vegetation provided additional cover and harbored invertebrates essential as food for young ducklings. Even though one type may have been utilized more often than another, broods preferred beaver ponds that had a diversity of vegative types. Broods that had a variety of types available were observed in all types at some time during the rearing period.

Riparian habitats, other than beaver ponds, were also important to the overall survival of broods. In all cases, hens utilized aquatic systems adjacent to the beaver ponds (creeks, lakes and temporarily inundated floodplains) when moving their broods from one impoundment to another. This was particularly important during the early brood rearing period when broods were most susceptible to decimating factors associated with terrestrial travel (Ball et al. 1975).

CONCLUSIONS

Beaver populations have increased rapidly throughout the southeastern United States in recent years. The general absence of effective management programs, and the availability in some states of unoccupied habitats, suggests continued increases can be expected in the future. Consequently, the extent of environmental and economic impacts of this expansion have not been fully realized. However, beaver ponds are a very valuable component of regional riparian ecosystems and efforts to implement effective management programs are needed.

Beaver ponds provided excellent habitats for numerous species of wildlife throughout the year. Because of the presence of water, physical and biological characteristics associated with the areas impounded by beavers were altered. This alteration apparently provided increased structural complexity and potential for production of important food items. As a result, through ecological mechanisms of resource parttioning, birds not normally associated with wetland habitats were attracted to the beaver pond and/or their adjacent edges.

The apparent interrelationships between avian species diversity and structural aspects of beaver ponds are in general agreement with reports in the literature for other types of habitats. However, since the general parameters of foliage height diversity, vertical strata diversity, percent volume cover, etc., did not apply well to beaver ponds (particularly those over 5 years old), there must have been a different set of structural parameters that were important. Collectively, these probably included a complex of

Table 4.--Utilization of wetland habitats by wood duck broods in South Carolina.

Habitat type[1/]	1BP	2BP	3BP	4BP	5BP	7BP	1TW	2TW	5TW	7TW	5R	7R
No. of broods having habitat type available	1	7	8	2	5	8	3	5	6	1	2	4
Mean percent of observed brood days (±S.D.)	4.0 --	26.7 (26.1)	33.6 (7.9)	0 -	24.5 (28.5)	19.4 (13.6)	6.5 (6.4)	12.4 (10.3)	5.3 (4.8)	1.0 --	12.5 (14.8)	1.5 (2.4)
Mean percent of expected brood days (±S.D.)	3.7 --	17.4 (14.9)	32.5 (22.7)	0.6 (0)	8.6 (8.3)	22.0 (11.0)	4.6 (2.1)	13.7 (9.3)	16.9 (10.0)	21.0 --	23.9 (8.7)	8.8 (1.2)
Mean difference (%)	+0.3[2/]	+9.3	+1.1	-0.6[3/]	+15.9	-2.6	+1.9	-1.3	-11.6	-20.0	-11.4	-6.3
t value	--	0.82	0.13	--	1.31	0.42	--	0.21	2.6*	--	--	5.5**

[1/] Habitat types: BP = beaver pond; TW = temporary wetland; R = riverine; see text for details.

[2/] ("+") designates preference.

[3/] ("-") designates avoidance.

*Significant at 0.05 level.

**Significant at 0.01 level.

factors such as, 1) increased habitat interspersion, 2) presence of several seral stages in close proximity to one another, 3) creation of forest openings, 4) presence of standing dead trees for insectivorous and cavity nesting species, 5) high aquatic insect populations serving as important avian food items, 6) abundant small seed crops for foods, and 7) a constant source of water.

In conclusion, we recognize that certain situations may warrant elimination of a beaver colony. However, for most situations the beavers should be managed as a renewable natural resource on the basis of an annual sustained harvest. Detrimental effects can be offset by opportunities for multi-use wildlife management at little or no additional costs to the landowner. Beaver ponds provide excellent habitat for game and nongame species of wildlife. Their value for waterfowl has been well established and with increased attention being given to the nonconsumptive utilization of wildlife resources, they could provide numerous opportunities for development of natural resource education programs.

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Leaf Litter Processing in Floodplain and Stream Communities[1]

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and
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Abstract.--Research has been based on the hypothesis that the floodplain serves as a preprocessing area for stream allocthonous material. In a Michigan woodland floodplain the major macroinvertebrate groups involved in leaf litter processing were the Oligochaeta, Diptera, Gastropoda, Diplopoda and Isopoda. Seasonal trends in macroinvertebrate abundance were generally bimodal, with peaks occurring in spring and fall. The major season for leaf litter processing in the floodplain was in the spring which was related to abiotic and biotic factors. Tethered leaves and coarse mesh bags containing confined litter placed in a woodland floodplain degraded annually at a significantly faster rate than leaf litter in medium or fine mesh bags, which degraded at approximately the same rate. The major time for stream litter processing occurred in the fall and winter with the Trichoptera, Plecoptera and Diptera (Tipulidae) constituting the major macroinvertebrate fauna. Overall ecological processes occurring in the floodplain were similar to those occurring in the stream, although the timing of leaf litter processing activity differed.

INTRODUCTION

The floodplain, like the sediments of running waters (Moon 1939, Cummins 1972), is an environment subjected to erosional and depositional forces in equilibrium. Functionally, the floodplain described in this study is analogous to the upper bank in Western watersheds and both are riparian zones influenced by the flooding regime of the stream. It is a depositional region with regard to the accumulation and temporary storage of organic debris resulting from litter fall and lateral movement and settled material as flood waters recede. It functions as an erosional region during flooding and runoff in that accumulated organic material is washed and transported from this area into the stream. The critical importance of the floodplain to the productivity of such large rivers as the Amazon has been proposed (Marlier 1973, Sioli 1975a,b). Nelson (1969) and Hynes (1975) have also inferred that it is largely the events occurring in the terrestrial environment (i.e., the riparian ecosystem) that determines the quantity and quality of organic materials streams receive. Sedell et al. (1974) found that in coniferous forests the organic material entering the stream from the bank was 1.5 times that of litter fall, indicating the importance of the upper bank as a temporary storage and potential preprocessing area for detritus such as leaf litter.

The maintenance of community structure and function in small streams is largely dependent on the input of organic matter from the autotrophically dominated terrestrial system (the watershed) through which the stream

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flows (Cummins 1974,1977; Sedell et al. 1974). In recent years a major emphasis in lotic research has been on the input and processing of coarse particulate organic matter (primarily leaf litter) as an energy substrate for aquatic organisms (Minshall 1967, Kaushik and Hynes 1971, Wallace et al. 1970, Cummins 1974, Suberkropp et al. 1975, and others). Evidence has suggested that allocthonous detritus input in woodland streams may support over 99% of the annual energy requirements for primary consumer organisms (Fisher and Likens 1972,1973). Much of this research has been concerned with the breakdown and decomposition of organic matter in the stream itself. Until recently, work on stream and forest floor soil leaf litter decomposition has been done independently with little interaction between disciplines (Edwards et al. 1970, Kaushik and Hynes 1971, Dickinson and Pugh 1974, Petersen and Cummins 1974, Anderson and Macfadyen 1976, Crossley 1977, Mattson 1977). A recent study by Brinson (1977) examined decomposition and nutrient exchange of litter in an alluvial swamp forest and Johnson et al. (1976) and Franz and Bazzaz (1977) studied the impact of the development or operation of reservoirs on floodplain forests. However, the floodplain has not been thoroughly investigated with regard to the role of invertebrates in leaf litter breakdown.

The major objectives of this research were to: 1) characterize the major floodplain macroinvertebrate community; 2) determine their role in leaf processing in a woodland floodplain; and 3) compare stream-floodplain interactions in relation to detritus processing.

METHODS AND PROCEDURES

Study Area

The Augusta Creek Watershed (Barry and Kalamazoo Counties, Michigan) encompasses an area of about 72 km^2 having an average slope of 2.03 m/km. First order tributaries are collected into two second order tributaries (after Strahler 1957) and the main stream, Augusta Creek, flows into the Kalamazoo River. The stream is a hardwater, brown trout habitat that drains woodland and marshland with some areas of agricultural, residential and recreational influence.

Research was conducted on the Augusta Creek floodplain located in the Kellogg Research Forest. At this location, Augusta Creek is a third order channel (approx. 10 m width; .75 m depth) with a discharge of 35-45 cfs. The floodplain (approx. 30-70 m) is heavily forested with a high diversity of lowland

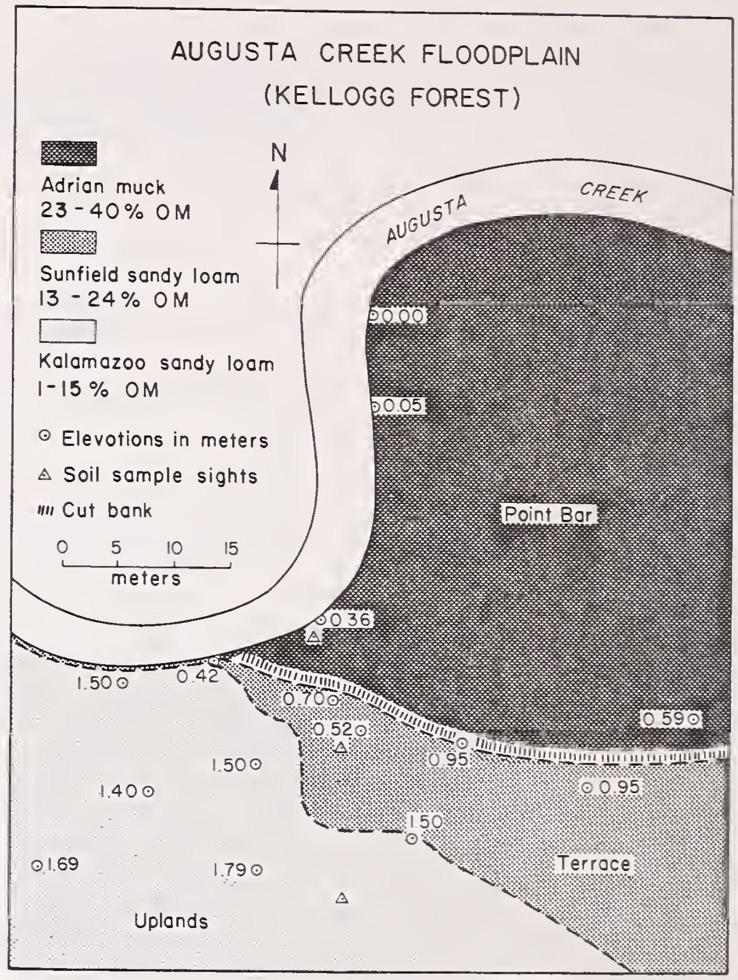

Figure 1.-- Soils and elevational map of Augusta Creek (Kellogg Forest) floodplain.

vegetation. Some of the major tree and shrub species are black ash (Fraxinus nigra Marsh), green ash (F. pennsylvanica Marsh), basswood (Tilia americana L.), dogwood (Cornus spp.), black cherry (Prunus serotina Ehrh.) and trembling aspen (Populus tremuloides Michx.). The dominant lowland herbaceous vegetation consisted of Jewel-weed (Impatiens capensis Meerb.), wood nettle (Laporta canadensis (L.)), running strawberry (Euonymus obovata Nutt), purple clematis (Clematis verticillaris D.C.), Iris sp. and violet (Viola sp.).

Because of its large size, the floodplain was divided into three areas based on vegetation, elevation and soil parameter gradients (fig. 1). The point bar is the area adjacent to the stream and the most frequently inundated area during annual flooding. This area consists of a poorly drained Adrain muck (Terric Medisaprist) which has the highest soil moisture and organic content of the three areas (figs. 1 and 2). The terrace consists of Sunfield sandy loam (Mollic Hapludalf) with a lower soil organic and moisture content (figs. 1 and 2). The upland site also consists of a well-drained sandy loam (Typic Hapludalf) with a low organic content and a soil moisture conent approximately equal to that of the terrace (figs. 1 and 2). The soil pH increases

with elevation from the Adrain muck in the point bar (pH 6.4) to the Kalamazoo sandy loam in the uplands (pH 7.3).

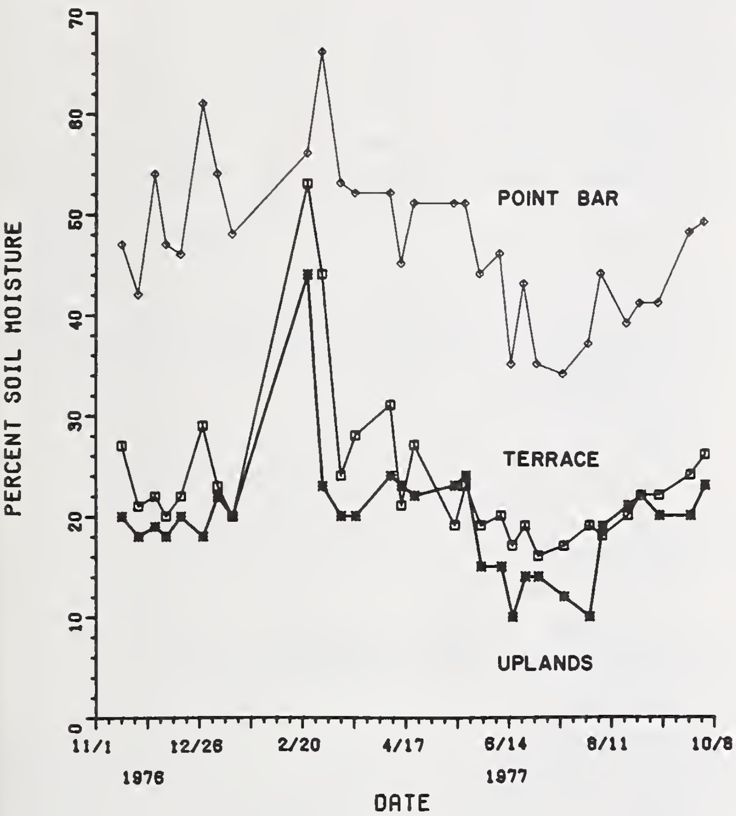

Figure 2.--Changes in soil moisture content at three sites on the Augusta Creek (Kellogg Forest) floodplain during 1976-77.

Floodplain mapping, soil and vegetational analysis indicate the deciduous forest soil in this study is most closely related to an organic profile of the "mull" type (Murphy 1955). There are no strongly structured horizons but a rather extensive zone of organo-mineral complexes, which range downward from the litter layer to the zone of weathered parent material (Wallwork 1976).

Measurement of Environmental Factors

The floodplain was surveyed and mapped using conventional methods described by Ruhe (1975). Soil core samples were taken for mechanical analysis and series identification. Soil temperatures were measured with recording thermographs, and soil moisture was determined gravimetrically for triplicate samples taken each collection date using a 50°C oven-dry method. Samples were then ashed at 550°C for 24 hours to assess percent organic matter. Macroclimatic data (temperature, rainfall) for the years 1976-77 were available from weather stations maintained by the Michigan State University Kellogg Biological Station (fig. 3).

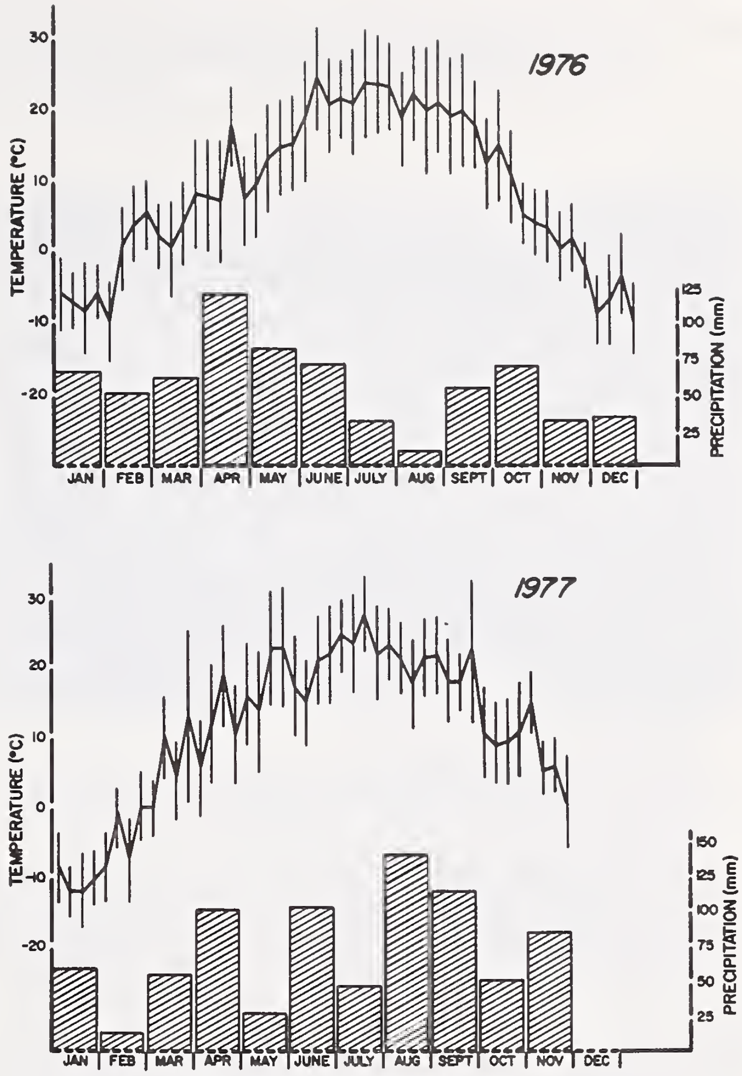

Figure 3.--Mean weekly maximum air temperatures and total monthly precipitation at Kellogg Biological Station during 1976-77.

Macroinvertebrate Sampling

A square box-type sampler (144 cm^2) modified from Healey and Russell-Smith (1970) was used to sample leaf litter macroinvertebrate abundance and diversity in the study area. Each sample consisted of litter and humus layers which generally corresponded to the "O" soil horizon (approx. 6 cm), consisting of loose leaves and other organic material in various stages of decomposition. Seven random samples were taken monthly from each area of the floodplain, except during the winter when a thick layer of floodplain ice prevented sampling. Box samples of litter and humus were returned to the laboratory and the macroinvertebrates were extracted with a modified Ladell (1936) apparatus utilizing wet sieving and flotation. Extraction efficiencies for the macroinvertebrates tested (e.g., earthworms, crane fly larvae) were 90-95%. Following extraction, animals were sorted, counted and identified. In addition to box samples, detailed field observations were made on the activity and feeding behavior of leaf litter

Table 1. A taxonomic listing of the leaf litter macroinvertebrates recorded from the Augusta Creek floodplain.

- ANNELIDA
  - Oligocheata
    - Enchytraeidae
    - Lumbricidae
      - *Lumbricus* spp.
- MYRIAPODA
  - Diplopoda
    - Julidae
      - *Ophyiulus pilosus* (Newport)
  - Chilopoda
    - Lithobiidae
- GASTROPODA
  - Pulmonata
    - *Catinella vermeta* (Say)
    - *Oxyloma retusa* (Lea)
    - *Strobilops labyrinthica* (Say)
    - *Succinea ovalis* (Say)
    - *Helicodiscus parallelus* (Say)
    - *Carychium exiguum* (Say)
    - *Zonitoides arboreus* (Say)
    - *Discus cronkhitei* (Newcomb)
    - *Cionella lubrica* (Nuller)
- CRUSTACEA
  - Malacostraca
    - Isopoda
      - *Tracheoniscus rathkei* Brandt
- INSECTA
  - Diptera
    - Tipulidae
      - *Tipula hermannia* Alexander
      - *Limnophila fuscovaria* Osten Sacken
      - *Shannonomyia lenta* (Osten Sacken)
      - *Erioptera caloptera* Say
      - *Epiphragma fascipennis* (Say)
      - *Molophilus huron* Alexander
      - *Atarba picticornis* Osten Sacken
      - *Nephrotoma alterna* (Walker)
      - *Gonomyia subcinerea* Osten Sacken
      - *Tipula dejecta* Walker
      - *Ormosia pyqmaea* Alexander
      - *Australimnophila toxoneura* (Osten Sacken)
      - *Ormosia manicata* (Doane)
    - Trichoceridae
      - *Trichocera bimacula* Walker
      - *Trichocera garretti* Anderson
      - *Trichocera hiemalis* (De Geer)

- Diptera (con't)
  - Sciaridae
    - *Bradysia* sp.
  - Cecidomyiidae
    - *Cecidomyiinae* (2 spp.)
    - *Lestremiinae* (2 spp.)
  - Scatopsidae
  - Mycetophilidae
    - *Mycetophila fisherae* (Laffoon)
    - *Mycetophila luctuosa* Meigen
    - *Gnoriste* sp.
  - Anisopodidae
    - *Sylvicola alternatus* (Say)
  - Ceratopogonidae
    - *Culicoides* sp.
  - Chironomidae (several spp.)
  - Phoridae
    - *Megaselia* sp.
  - Empididae (several spp.)
  - Dolichopodiae (several spp.)
  - Platypezidae
  - Stratiomyidae
  - Micropezidae
    - *Compsobata univitta* (Walker)
  - Muscidae
    - *Fannia brevipalpis* Chillcott
- Coleoptera
  - Cantharidae
  - Carabidae
  - Colydiidae
  - Curculionidae
  - Elateridae
  - Helodidae
  - Hydrophilidae
  - Staphylinidae

invertebrates throughout the year.

Leaf Litter Degradation and Processing

In the present study, confined litter in nylon bags (10 x 10 cm) of three different mesh sizes, similar to those employed by other workers (Crossley and Hoglund 1962, Heath et al. 1964, 1966, Anderson 1973) were used to exclude selected organisms (fig. 4). Leaves of black ash (F. nigra), a dominant riparian deciduous species in this study, were collected in catch nets shortly after abscission, air-dried for one week, weighed into 4-g amounts and the weights recorded. Pre-weighed leaves were then soaked in non-clorinated water overnight, placed in mesh bags and sealed. The following three mesh sizes were chosen (fig. 4):

a) 50 µm - to exclude all soil invertebrates and allow only leaching and microbial decomposition.

b) 500 µm - to admit microarthropods (mites, Collembola and enchytraeids) and exclude most macroarthropods.

c) 8000 µm - admit all soil fauna (microarthropods, macroinvertebrates) including earthworms and Mollusca.

Since estimates of sample decay rates in litter bags have been substantially lower than those observed with tethered leaves (Witcamp and Olson 1963, Anderson 1973), both techniques were used to provide estimates of upper and lower limits of litter degradation (fig. 4). In October 1977, 400 litter bags and tethered leaf samples were randomly distributed among the three areas of the floodplain and buried in a random pattern between the litter and humus layers. A subsample of litter bags was immediately returned to the laboratory, oven dried and ashed at 550°C for the assessment of weight loss due to leaching, breakage and handling. A total of three replicate litter bags of each mesh size and two replicates of tethered leaves were collected monthly (except during ice cover) from all areas for a 12-month period. Leaves were removed from bags in the laboratory, carefully brushed free of animals and loose detritus, ashed at 550°C and reweighed to determine the percent of leaf material remaining over time. Animals from bags were sorted, identified and preserved for additional analysis.

Litter Bag Analysis

The analysis was directed at defining the biotic and abiotic components of leaf litter degradation in a woodland floodplain ecosystem. By partitioning the natural decay processes into discrete "feeding" units (as defined by the three mesh bag sizes) the biological activity, expressed as leaf weight loss over time, can be defined and assessed separately.

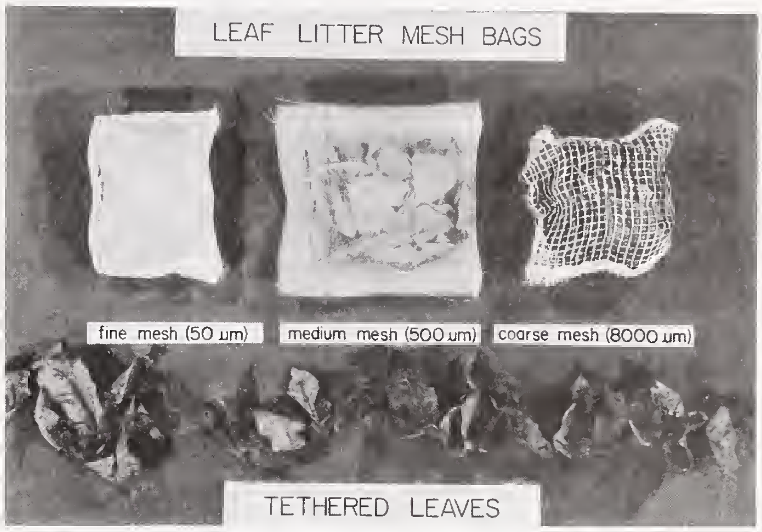

Figure 4.--Different sized mesh bags used for leaf litter processing experiments.

The amount of leaf material lost over a period of time can be expressed as the percentage remaining after a given time and calculated by:

$$\% R = W(t_f)/W(t_i) \times 100$$

where $W(t_i)$ is the initial weight of leaf material and $W(t_f)$ is the amount of material remaining after time t. The values can be expressed as % loss/day for comparison of sites and seasons.

RESULTS AND DISCUSSIONS

Floodplain Macroinvertebrate Fauna

Six major groups of floodplain macroinvertebrates associated with leaf litter processing were collected and identified, consisting of approximately 35 families, 40 genera and 55 species (table 1). Although the Coleoptera were well represented (table 1), most species sampled were predators and not considered to be directly associated with litter degradation. The microfauna (i.e., Nematoda, Acarina, Apterygota, Collembola) were also monitored throughout the study; however, the faunal extraction technique was primarily designed for macroinvertebrates and microfaunal density counts were generally underestimated.

Seasonal changes in relative abundance for each major floodplain macroinvertebrate group during 1976-77 in the point bar and upland are compared in figure 5. For most

groups, there was a marked increase in abundance at both sites during the spring and again in early fall 1977. Studies have shown that seasonal distributions of decomposer invertebrates vary among regions according to local climatic conditions (van der Drift 1951, Huhta et al. 1967, MacLean and Pitelka 1971, Merritt and Anderson 1977, McBrayer et al. 1976). Our findings agree with those of McBrayer et al. (1976) in the southeastern United States who found invertebrate populations to be bimodal, with lows during the winter when the soil was both cold (or frozen) and saturated, and in summer when high evapotranspiration reduced soil and litter moisture to an annual minimum (fig. 2). The downward vertical migration by soil animals to escape cold surface temperatures during winter and desiccation in the summer has been reported elsewhere (van der Drift 1951, Macfadyen 1952, Belfield 1956, Usher 1970), and probably explains the summer and winter lows recorded in this study. Also, summer is the time when many larval insects, particularly Diptera, emerge as adults from the soil, thus reducing population densities (Healey and Russell-Smith 1971). The annual spring peak shown (fig. 5) is well documented (Kuhnelt 1976, Wallwork 1976) and often coincides with warming temperatures (fig. 3). Increased soil invertebrate activity and abundance in early fall (late August and September) coincided with an increase in monthly precipitation during that time (fig. 3). Weese (1924) has also attributed part of the fall maximum to animal species which seek leaf litter and soil for hibernation.

Although temperature and moisture significantly affect the activity of leaf litter invertebrates (Witcamp and van der Drift 1961, Huhta et al. 1967, Madge 1969, Edwards et al. 1970, and others), groups such as the Isopoda and Diplopoda showed irregular fluctuations (fig. 5). These variations could be due to sampling error (e.g., aggregated distributions) or some additional factor(s), such as life cycle differences and/or food availability at a particular time (Macfadyen 1952; see later discussion). Annual flooding did not appear to significantly influence macroinvertebrate abundance, since the water year 1976-77 was unusually dry (fig. 3), and little flooding occurred during the study period.

There were generally greater numbers of individuals/meter^2 recorded from the point bar than the uplands (fig. 5). This was particularly true of the Gastropoda, Enchytraeidae and Diptera which decreased in abundance on an elevational gradient running from the stream bank to the upland. Because of their intermediate size, there was some question whether enchytraeids should be considered "macroinvertebrates". However, due to their great abundance in this study, they were considered part of the macrofauna. This elevational trend was related to changing soil moisture content (fig. 2), and to a lesser extent soil organic content between these areas (fig. 1). There was a significant correlation ($r^2 = 0.80$) between soil moisture and soil organic content in the floodplain. The three faunal groups mentioned above are often more abundant in moist and highly organic soils and some species are able to survive short periods of flooding (Crisp and Lloyd 1954, Nielsen 1955, Perel et al. 1971, Kuhnelt 1976, Frey and Edgar 1977). Using stepwise multiple regression, the abundance of one major dipteran family, the Tipulidae, was related to environmental parameters. Moisture was found to be the most significant predictor of tipulid abundance. Other predictors in decreasing significance were: collection date (seasonal occurrence), soil organic content and sampling locality.

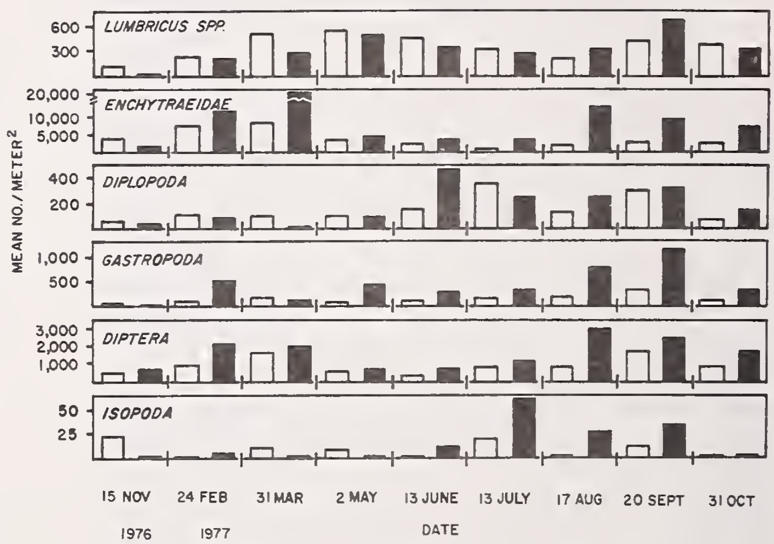

Figure 5.--Seasonal changes in relative abundance of soil and litter macroinvertebrates in the point bar (■) and upland (□) areas of the floodplain.

The species composition within different groups also changed with increasing soil moisture. Significantly fewer species of Tipulidae ($P < 0.05$) inhabited the upland area than the point bar or transition zone (terrace). This was expected, since many tipulids have the physiological and morphological adaptations to survive in moist habitats subject to annual inundations (Rogers 1933, Crisp and Lloyd 1954). In other macroinvertebrate groups (e.g., Diplopoda, Isopoda, Lumbricus spp.), the relationship between increased soil moisture and animal abundance was not as clear.

Few investigations have actually dealt with the arthropod community of floodplains. Goff (1952) described a large river floodplain animal community in Illinois and found flooding to be influential in the distribution of earthworms. Uetz (1976) showed that spider community diversity and abundance in an Illinois streamside forest increased with elevation above the floodplain, which might be expected of a less water-dependent community. He found that frequent inundation and fluctuating moisture levels at lower elevations limited the distribution of many spider species and their prey. Bell and Sipp (1975) working on the same floodplain showed, by combining the caloric content of leaves with leaf litter gradient, a linear relationship between elevation and available energy for leaf litter consumer organisms.

Except for the earthworms and gastropods, the numbers/m^2 of major floodplain macroinvertebrates recorded in this study fell within the range of other published studies (Bornebusch 1930, Cragg 1961, Zachariae 1965). The high densities recorded for these two groups could have been due to differences in sampling and/or extraction efficiencies, or because of the highly organic nature of the floodplain soil. As Phillipson et al. (1978) found in a comparative study on earthworm numbers and biomass in a Beech woodland, soil type was more important than the dominant tree leaf litter in determining earthworm abundance.

Leaf Litter Processing in the Floodplain

The results of the experiment on the degradation rates of confined and non-confined ash litter in the point bar area of the floodplain are presented in figure 6. The graph shows the marked differences in the percent of weight remaining after each collection. Initial weight losses from bags and tethered leaves were due to rapid leaching loss of soluble leaf components (Nykvist 1959, Gilbert and Bocock 1960, Anderson 1973), and breakage and handling loss during sampling (approx. 10%). In addition to the decay of easily decomposable substances, the litter is subjected to precipitation during the fall and winter and loses weight by the leaching of soluble products and by the activities of the microflora and microfauna (Witcamp and Olson 1963). From monthly observations of leaf litter in the field and litter bag analysis, there was no evidence of feeding activity by the litter fauna during fall and winter. This finding agrees with related studies in terrestrial and aquatic habitats which have shown that freshly fallen leaves are not fed on by detritivores for several weeks after leaf fall, although they are invaded by microorganisms, especially fungi (Edwards et al. 1970, Kaushik and Hynes 1971, Petersen and Cummins 1974, Suberkropp and Klug 1976). During this period, leaf palatability to litter detritivores is greatly improved by weathering and microbial colonization (van der Drift 1951, Minderman and Daniels 1967, Kaushik and Hynes 1971). A marked increase in weight loss occurred in both confined and non-confined litter in March and April 1977 (fig. 6), which coincided with increasing temperatures, precipitation and annual flooding, as well as the spring maximum of floodplain macroinvertebrates (figs. 3 and 5). Accelerated decomposition continued through spring and decreased during summer with increasing soil temperatures and decreasing precipitation.

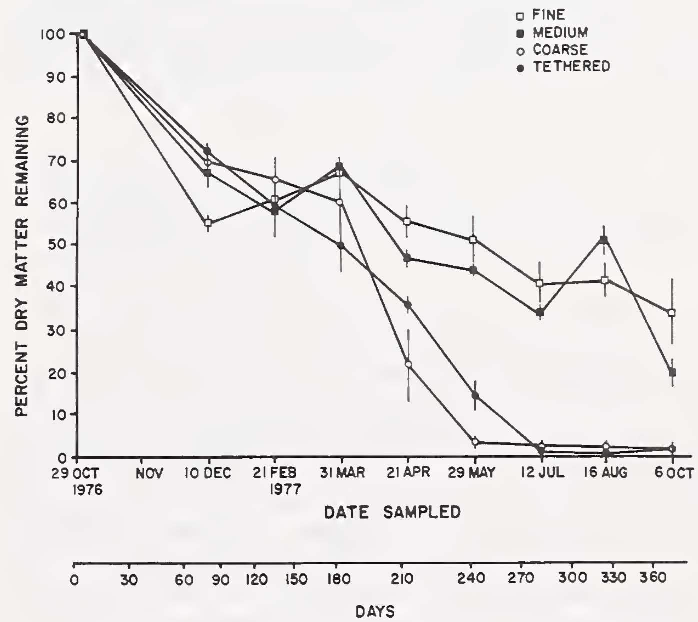

Figure 6.-- Weight loss of confined (different sized mesh bags) and unconfined (tethered) ash leaf litter in the point bar area of the floodplain, expressed as percent of dry weight remaining with 2 s.e.. Litter bags and tethered leaves were placed in floodplain on 20 October 76.

Comparison of confined and non-confined litter revealed important differences in rates of leaf litter weight loss in the floodplain (fig. 6). The apparent increase in litter weight in fine and medium bags during winter was due to the variation between replicate bags on different collection dates. This variation may have been related to the observed excess moisture compacted and held within fine and medium bags and thus resulted in differential leaching rates between bags. Witcamp and Olson (1963) found that bagged leaves contained almost twice as much moisture as tethered leaves during certain seasons. Considering these differences, there was a similarity in breakdown rates between confined

and unconfined litter before March 1977, and then a sudden increase in the rate of breakdown of tethered leaves and coarse mesh bags after March. Weight loss was significantly faster ($P < 0.05$) from tethered leaves and those in coarse mesh bags than from leaves in medium and fine bags, and there was little or no leaf tissue left (<1%) 12 months after the start of the experiment. Weight loss from fine and medium bags was slower and 20-35% of the detritus remained after 12 months. Tethered leaves and those in coarse mesh bags lost 54-57% of their dry weight during a 60-day period (March-May), while leaves in fine and medium mesh bags lost only 16-25% of their weight during the same time period. Although Witcamp and Olson (1963) found that Quercus leaves decayed more than twice as fast when tethered then when confined in coarse litter bags, the coarse mesh size employed was considerably smaller (1 mm) than used in this study (8 mm). Our findings agreed with those of Woodwell and Marples (1968) who used a slightly larger mesh size (2 mm) and showed similar decay rates using the tethering technique and litter bag method.

Leaves put into fine mesh bags (50μ), which completely excluded soil animals and allowed only leaching and microbial decomposition, showed the slowest breakdown rates. This suggested that without some preliminary fragmentation by soil animals, the microorganisms cannot decompose the constituents of some leaf species (Edwards and Heath 1963). In turn, fragmentation of leaf litter by arthropods may expose a greater surface for microbial action and leaching (Witcamp and Crossley 1966). Differences between breakdown rates in fine and medium bags (which admitted microarthropods) were not significant ($P > 0.05$); suggesting that the role of microarthropods in leaf litter breakdown in this floodplain habitat was not as significant as reported elsewhere (Madge 1969, Harding and Stuttard 1974).

The marked differences shown in leaf litter breakdown rates between fine or medium mesh bags and coarse bags or tethered leaves reflects the importance of the soil macroinvertebrates on floodplain litter breakdown. Further evidence of their role in this study comes from the analysis of soil core samples (see earlier section), the animals extracted from litter bags and detailed field observations. Although the earthworms appeared to contribute substantially to litter breakdown, it was not possible at this time to define the relative importance of each macroinvertebrate group in the disappearance of litter from the bags. Other major groups involved were the Diptera larvae, enchytraeids, millipedes, gastropods and isopods. Similar leaf litter breakdown studies in deciduous forests containing a "mull" type soil have shown the greater importance of the macrofauna than microfauna in fragmenting and processing litter (Bocock and Gilbert 1957, Kurcheva 1960, van der Drift 1963, Edwards and Heath 1963, Edwards 1974). Although macroinvertebrates were shown to be important in this study, the process of weathering is also an important cause of weight loss, particularly in a floodplain subjected to annual floods, yet it is perhaps the hardest factor to isolate (c.f., Mason 1977).

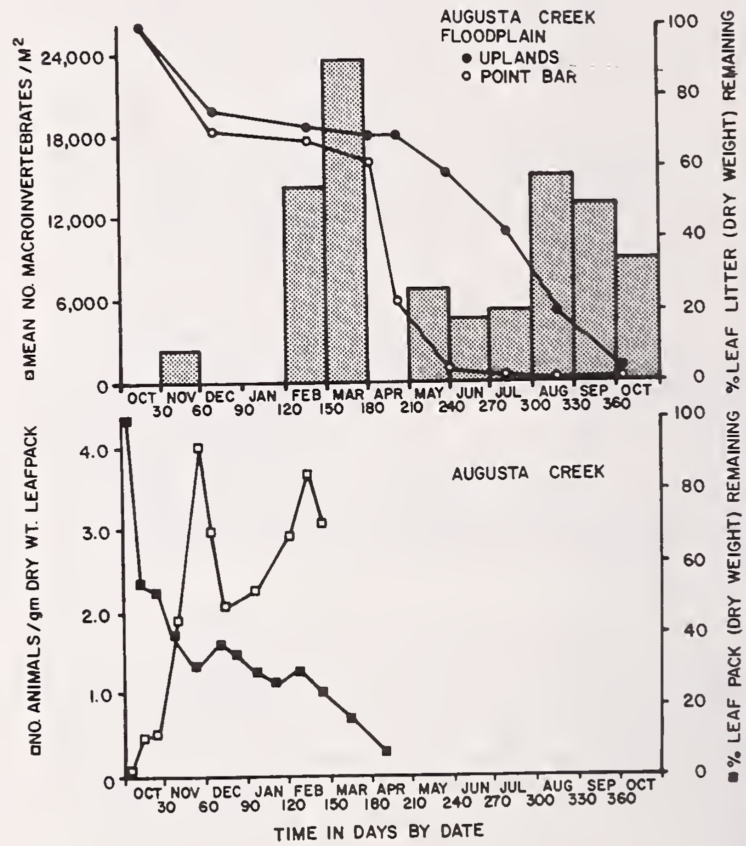

Figure 7.--A comparison of ash leaf litter processing and seasonal changes in litter macroinvertebrate densities between the Augusta Creek floodplain and stream. Leaf pack and litter bag weight losses reported by percent remaining. Stream data taken from Petersen and Cummins (1974) and Cummins (unpubl. data).

Leaf Litter Processing in Different Areas of the Watershed: A Comparison

A comparison between leaf litter (F. nigra) processing rates and the annual dynamics of the associated fauna in a stream and floodplain are shown in figure 7. Due to the continual movement of litter macroinvertebrates in and out of the coarse mesh bags during feeding,

it was not possible to obtain accurate litter bag animal densities each sampling date. Therefore, seasonal floodplain macroinvertebrate abundance trends were used for comparison with data on leaf pack animal processing in the stream.

The major time for detritus processing by aquatic invertebrates in a small woodland stream (Augusta Creek) is in the fall and winter (Petersen and Cummins 1974; Fig. 7, bottom). The two seasonal peaks shown in leaf pack animal densities represent the presence of different functional groups (Merritt and Cummins 1978). Leaf packs are colonized in the fall by large particle detritivores (i.e., shredders) that remove large chunks of leaf material. In the winter, packs are mainly colonized by fine particle feeders (i.e., collectors) that feed on the surface of leaf material or aid in fragmentation. As was shown with floodplain leaf litter processing, soluble organic matter is leached from leaves in the stream, the majority of which occurs in the first 24 hours of initial wetting (Petersen and Cummins 1974, Cummins 1974). Also, the leaves undergo a period of colonization by microorganisms before the animals will readily feed on the material (Suberkropp and Klug 1976). A leaf entering the stream from September-October would not be found in a recognizable form or in a leaf pack after April-May (Petersen and Cummins 1974; Fig. 6).

In contrast, the major time for leaf litter processing in the floodplain was in the spring when high densities of some major floodplain macroinvertebrates occurred (figs. 5 and 7, top). After March, there was a significant decline in the per cent leaf litter weight remaining in coarse mesh bags and by October and November confined litter in both the point bar and uplands was gone, respectively (fig. 7). The litter processing rate in the point bar was significantly faster ($P < 0.05$) than that in the upland with less than 5% leaf litter remaining in the former by the end of June. The difference in rates can be attributed to several factors, including a greater diversity and abundance of certain leaf litter macroinvertebrates in the point bar, higher soil moisture and differences in other edaphic conditions (see earlier sect.). Litter processing rates in the terrace (transition zone) fell between those values shown for the point bar and uplands. Morphological changes in leaves confined in coarse mesh bags among different areas of the floodplain are shown in fig. 8. In the point bar only petioles and larger leaf veins remained after eight months, while in the terrace and uplands there was progressively more whole leaf material remaining.

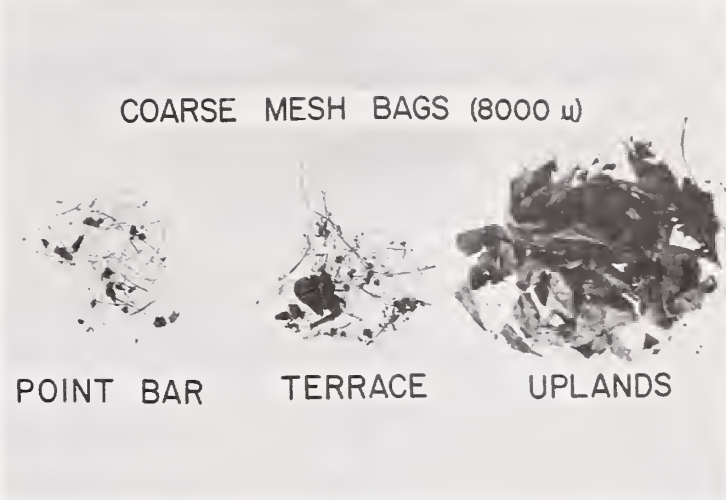

Figure 8.--Leaf processing at three sites on the Augusta Creek floodplain as demonstrated with the litter bag bioassay method. Photographs were taken after 8 months exposure in the field.

It is generally assumed that the fall maximum of many soil arthropods is due to climatic factors, such as increased soil moisture (Macfadyen 1952, Kuhnelt 1976). However, it was not clear what the macroinvertebrate food resource was during the fall when there was little leaf litter remaining on the floodplain to degrade (fig. 7). It would not appear that they were feeding on freshly fallen litter since it was shown earlier that leaf litter dropped in the fall was not fed on by the macroinvertebrate fauna for several weeks until it was conditioned by microorganisms. However, Striganova (1971) found diplopods feeding on newly fallen leaves in the autumn which were hardly attacked by microbes. One possible explanation is that the immature stages of several macroinvertebrate groups, particularly Insecta, are preparing to overwinter in the soil and are in a non-feeding stage. Another explanation is the fauna are feeding on the decomposed organic matter that has accumulated from the previous spring and summer, or they may be feeding on the abundant decaying lowland shrub and herbaceous vegetation in the floodplain. Bell et al. (1978) found a significant accumulation of soil organic matter in an Illinois streamside forest from September to the following fall and they attributed the accumulation to the onset of warmer spring temperatures and the decomposition of leaf litter. Wallwork (1976) has also emphasized the importance of ground vegetation in

influencing soil arthropod species diversity and abundance in some areas. Whether or not the fall peak was due to differences in functional groups, as shown with stream leaf pack processing, is not possible to ascertain at this time. As litter macroinvertebrate biomass values become available, a better understanding of the above interactions should follow.

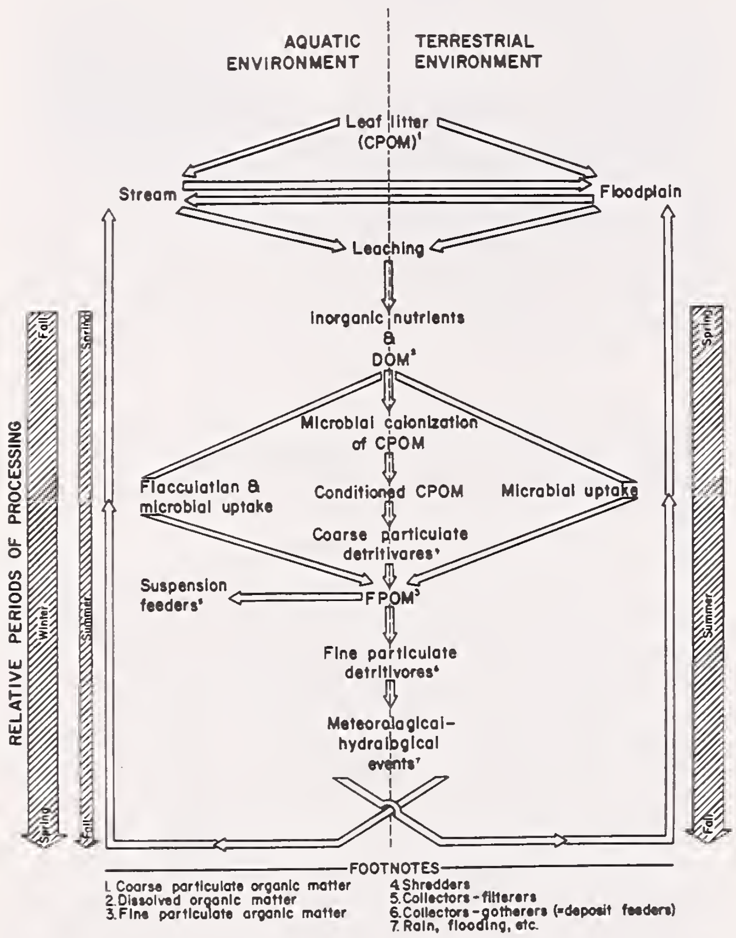

Figure 9.--A diagramatic representation of the processes and interactions occurring in a woodland stream and floodplain with regard to the processing of leaf litter.

CONCLUSION

Our study has shown that the overall ecological processes occurring in the flood-plain are similar to those occurring in the stream (fig. 9). The floodplain represents an intermediate area which is influenced by the stream or river and yet is mainly a terrestrial environment. Both systems are interacting and continually exchanging detrital material, although it is not known in which system there is a net gain over annual and longer cycles. Leaf litter falling into the stream or onto the floodplain is leached and colonized by microbes (fig. 9). The flocculent material generated from forest debris may be captured by rivers and streams during the annual flood and withdrawn into the channel by return flows. Functional decomposer groups operate in both systems (table 2), although the timing of leaf litter processing activity may differ somewhat (fig. 9). Over time, annual meteorological and hydrological events will serve to transport particulate organic matter into the stream from the floodplain and/or onto the floodplain from the stream. These events also play an important role in floodplain formation.

Current work has focused on the basic structure and organization of floodplain or wetland macroinvertebrate communities involved in the breakdown of organic matter. Initial findings suggest that the leaf litter macroinvertebrate community inhabiting a woodland floodplain consists of an assemblage of different species unique to this ecosystem. A better knowledge of the function of the floodplain macroinvertebrate community in leaf litter degradation and a more thorough understanding of stream-floodplain interactions should aid ecologists in attempting to provide answers to the following complex questions: 1) what is the particle size and quantity of preprocessed CPOM (coarse particulate organic matter) entering the stream from the flood-plain? That is, how important is the flood-plain to the stream as a preprocessing area for leaf litter (Cummins 1977); 2) what are the important factors in the functional linkages between terrestrial and aquatic ecosystems as discussed by Likens and Bormann (1974) and Hasler (1975); and 3) what are the ecological processes occurring in the floodplain that are critical to the proper maintenance and management of stream eco-systems as valuable natural resources (c.f., Karr and Schlosser 1978). Research in these areas could supply important information for the development of land-water interface models of watershed ecosystems.

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Table 2. Major macroinvertebrate groups associated with leaf litter processing in a Michigan woodland watershed (Augusta Creek)

Watershed Habitat	Major macroinvertebrate groups	Comments
Stream	Amphipoda (mainly Gammarus); Insecta-Plecoptera (mainly Pteronarcidae); Trichoptera (Limnephilidae, Phryganeidae, Lepidostomatidae); Diptera (Tipulidae, some Chironomidae)[1]	Groups listed are mainly large particle feeders and totally aquatic as immatures, although terrestrial limnephilid caddisflies have been recorded.[2] Also, amphipods, tipulids and chironomids have terrestrial analogues.
Floodplain	Oligochaeta (Enchytraeidae, Lumbricidae); Gastropoda (Pulmonata); Diplopoda (mainly Julidae); Isopoda (Trachelipus sp.); Diptera (mainly Tipulidae, Sciaridae and Chironomidae); Coleoptera (mainly predators)	Consists of both semi-aquatic and terrestrial groups. Many floodplain species have the physiological and morphological adaptations to survive in moist habitats subject to annual inundations. Higher diversity and abundance of specific groups, especially Diptera.
Uplands	Similar faunal representation as floodplain but species composition changes	Consists mainly of terrestrial species not capable of surviving periods of inundation and areas of high soil moisture. Lower abundance of some groups, particularly Diptera, Enchytraeidae and Gastropoda, and greater abundance of some Coleoptera.

1 Taken from Petersen and Cummins (1974) who have worked on leaf litter processing in the stream of the Augusta Creek Watershed

2 See: van der Drift and Witkamp (1960) and Anderson (1967)

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The Relation of Flood Timing and Duration to Variation in Bottomland Hardwood Forest Community Structure[1]

Robert Terry Huffman[2&3]

Abstract.--Variation in bottomland hardwood forest community structure within the Ouachita River Drainage Basin in southern Arkansas was found to be related to the timing and duration of floods during the growing season. Seedling and sapling development of ironwood (Carpinus caroliniana), cherrybark oak (Quercus falcata var. pagodaefolia), water oak (Q. nigra), sweetgum (Liquidambar stryaciflua), and blackgum (Nyssa sylvatica) were significantly correlated with varied flood timing and duration patterns occurring between 1962 and 1974.

An understanding of the effects flood timing and duration have on floodplain vegetation should be considered fundamental for the development of: (1) environmental impact assessments; (2) jurisdictional criteria for delineation of wetlands from nonwetland areas; and (3) flood prediction capabilities where standard stream gaging techniques are either unreliable or impractical.

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Relating Human Activities and Biological Resources in Riparian Habitats of Western Texas[1]

David J. Schmidly[2] and Robert B. Ditton[3]

Abstract.--This paper discusses the recreational and wildlife values of riparian habitats along the Rio Grande in western Texas (from El Paso to Del Rio). Several human activities have the potential or have in fact impacted on riparian resources in this region. These include: (1) irrigation diversions and stream channelization which greatly alter rates and amounts of water flow; (2) land flooding resulting from reservoir construction; (3) land clearing for purposes of cultivation to increase agriculture production; (4) overgrazing by domestic livestock; (5) introductions of exotic plants and fishes; (6) increases in human recreation activity (floating, camping, hunting, and trapping); and (7) pesticide buildups which have accumulated as a result of drainage and erosion from nearby fields. Contract research with the National Park Service at Big Bend National Park and Amistad Recreation Area focused on outdoor recreation and grazing impacts and findings are reported elsewhere. This paper seeks to place these impacts into broader land use perspective so that riparian resources can be more effectively managed in western Texas.

INTRODUCTION

The most extensive riparian habitats in western Texas exist wherever periodic flooding occurs along the Rio Grande. In the past few years biologists and resource managers have realized that substantial numbers of both game and non-game wildlife species are dependent upon riparian vegetation and that these habitats have remarkably high wildlife potential. At the same time, it has also been demonstrated that riparian communities support a level of outdoor recreation activity that is greatly disproportionate to their limited linear acreage.

Exploitation by man has greatly altered the riparian habitats of the southwest, and, in the last 100 years, the rate of alteration has increased significantly (Davis, 1977). This is due largely to ever-increasing human pressures which include the following: (1) irrigation diversions and stream channelization which greatly alter rates and amounts of water flow; (2) land flooding resulting from reservoir construction; (3) land clearing for purposes of cultivation to increase agriculture production; (4) overgrazing by domestic livestock; (5) introductions of exotic plants and fishes; (6) increases in human recreational activity (floating, camping, hunting, trapping, etc.); and (7) pesticide buildups which have accumulated as a result of drainage and erosion from nearby fields. The Rio Grande of western Texas has been influenced in one way or another by each of these activities. For the most part, basic information about riparian habitats along the Rio Grande has been lacking and this has hindered the development of realistic management plans to effectively conserve this important resource.

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RESEARCH PROGRAM

In response to the need for additional information concerning riparian habitats in western Texas, the National Park Service (NPS) contracted us to conduct human impact studies in Big Bend National Park (BBNP) and Amistad Recreation Area (ARA) in 1976 and 1977, respectively. Both of these areas are situated in the Rio Grande river system and in recent years both have experienced dramatic increases in recreational and water resource use. Both projects were interdisciplinary in that they involved biological and social scientists and both considered these four elements: the resource, the user, human use impacts, and management alternatives.

The methodology and results of our research projects at BBNP and ARA are presented elsewhere (Boeer, 1977; Boeer and Schmidly, 1977; Ditton and Schmidly, 1977; Ditton et al., 1977; Schmidly and Ditton, 1976, 1979; and Schmidly et al., 1976) and need not be repeated in detail here. Instead, we will summarize the major findings of our research and relate these to other factors impacting riparian ecosystems along the Rio Grande in western Texas (from El Paso to Del Rio) as documented by others.

DESCRIPTION OF THE RIO GRANDE CORRIDOR

Physiography

By the time the Rio Grande reaches Texas, it is nothing but a small stream and most of its waters are diverted to irrigate fields south and east of El Paso. The stream is dry for much of the next 100 miles (mi) between El Paso and Ft. Hancock, but southeast of Ft. Hancock the river valley narrows and ground water surfaces to form a salty stream. The river remains small until just about Presidio where it is rejuvenated by the waters of the Rio Conchos, which is estimated to supply 18% of the Rio Grande's total flow. Granero Dam, constructed in 1964 on the Rio Conchos in Chihuahua (Mexico), greatly restricts water flow into the Rio Grande during certain times of the year.

The most pristine and unchanged portion of the Rio Grande is within a 200 mi strip that lies between the western edge of BBNP and Langtry, Texas. Topography along this stretch of the river includes (1) sheer wall canyons (Santa Elena and Mariscal canyons) with few areas of alluvial deposits; (2) long deep canyons (Boquillas and the "Lower Canyons") where the walls do not rise abruptly and where larger areas of alluvial deposits occur; and (3) areas of broad flat floodplain with extensive alluvial deposits.

The impounded waters of Amistad Reservoir reach their westernmost limits near Langtry. The character of the river between Langtry and Del Rio has been altered considerably since the construction of Amistad Dam. Prior to construction of the dam, the landscape of the region consisted primarily of steep river canyons and dry tributaries characterized by cliff overhangs, scoured canyon floors, and bedrock potholes. Bordering the steep river canyons and tributaries, the landscape was generally hilly to rolling. Since the filling of the lake commenced in 1978, over 100 mi of this limestone canyon country has been inundated. The filling of the reservoir completely inundated many of the shorter cliffs while only partially covering the higher ones so that today an uncalculated surface is under water.

Vegetation

Floodplain or riparian vegetation exists wherever periodic flooding occurs along the Rio Grande except where sheer cliffs rise directly out of the riverbed. These areas may extend from a few feet to one-half mile from the river channel; furthermore, adjacent arroyos and creeks may carry enough surface or ground water to produce a similar floodplain environment.

The bottomlands of the Rio Grande are choked with salt cedar (*Tamarix gallica*), mesquite (*Prosopis* sp.), willows (*Salix* sp.) and an occasional cottonwood (*Populus* sp.). Much of the water of the Rio Grande below El Paso comes from the Rio Conchos that enters above Ojinaga, Mexico, across from Presidio. As a result of this great river much of the Rio Grande from Presidio to Amistad Dam supports two large grasses (called river cane) on its banks, namely the exotic giant reed (*Arundo donax*) and the common reed (*Phragmites communis*). River cane, willow, and mesquite grow so dense in many places along the river that it is often difficult to get out on the banks of the river. Bermuda grass (*Cynodon dactylon*) is common in protected areas along the river (called vegas) except where dense river cane grows.

Other mesic plants that commonly grow in riparian habitats along the Rio Grande include seepwillow (*Baccharis glutinosa*), honey mesquite (*Prosopis glandulosa*), desertwillow (*Chilopsis linearis*), tree tobacco (*Nicotiana glauca*), and screwbean (*Prosopis pubescens*). Occasionally ponds are formed where the river changes its course or where high water has dredged a deep hole or scour. Common plants which occur in the silty soils around these

ponds include seepwillow, salt cedar, cottonwood, and common cattail (Typha latifolia).

Vertebrate Fauna

Riparian ecosystems are of paramount importance in producing and maintaining a large degree of the biotic diversity along the Rio Grande in western Texas. The Rio Grande traverses the Chihuahuan Desert and the mesic riparian situations along the river serve as suitable habitat for many vertebrates, which otherwise could not exist in this region of harsh desert climates. At least 61 species of vertebrates live along the Rio Grande in western Texas and are dependent upon riparian habitats for their existence. These include 35 fishes (see Hubbs et al., 1977 for a complete list), 11 amphibians and reptiles, 13 birds, and 3 mammals. A host of other vertebrate species also live in riparian habitats, but they are not restricted to or dependent on these places for their survival.

Among vertebrates, fishes are the group most dependent upon riparian ecosystems for their survival. Hubbs et al. (1977) documented the fishes of the middle part of the Rio Grande and divided them into three faunal assemblages: the Saline Rio Grande fauna (made up of widely distributed and salt tolerant species) upstream from the Conchos confluence; the Rio Conchos-Rio Grande fauna between the Conchos and Pecos rivers; and the Tributary creek fauna that depend on tributary creeks for all or part of their life history stages. At least two presumed endangered species (Notropis simus and Scaphirhynchus platyrynchus) have already been eliminated from the Tributary creek fauna.

Conant (1977) has studied the distributions of semiaquatic reptiles and amphibians in the Chihuahuan Desert and the following list of Rio Grande species is taken from his paper. Many of these species are common in more mesic habitats outside of the desert and exist only as relict populations in the riparian habitats of the Rio Grande. Two toads (Woodhouse's toad, Bufo woodhousei, and the Gulf Coast toad, B. valliceps) are common, although the former species has a wider distribution than the latter. Turtles which have been recorded along the Rio Grande include the slider turtle (Chrysemys concinna), painted turtle (Chrysemys picta), pond slider (Chrysemys scripta), spiny softshell turtle (Trionyx spiniferus), and the Big Bend mud turtle (Kinosternon hirtipes). Common snakes include the common garter snake (Thamnophis sirtalis), the western ribbon snake (Thamnophis proximus), the diamondback water snake (Natrix rhombifera), and the plain-bellied water snake (Natrix erythrogaster). All of these riparian herptiles would be profoundly affected by any marked dimunition or interruption of stream flow or elimination of the gallery forest as a result of subnormal rainfall or the activities of man (Conant, 1977).

Birds also exhibit a strong riparian dependence and this relationship has been well quantified. The Rio Grande corridor serves as a significant migratory and emigration route for avifauna, and 38 species are known to nest within the riparian habitat (Wauer, 1977). The Rio Grande also provides suitable habitat for 40% of the 94 birds known to breed within riparian systems within the American southwest. Several breeding birds known to occur within the Big Bend country appear to owe their presence there to the river corridor (Wauer, 1977). These include the orchard oriole (Icterus spurius), hooded oriole (I. cucullatus), great-tailed grackle (Quiscalus mexicanus), green kingfisher (Chloroceryle americana), great-crested flycatcher (Myiarchus crinitus), great blue heron (Ardea herodias), green heron (Butorides striatus), peregrine falcon (Falco peregrinus), white-winged dove (Zenaida asiatica), screech owl (Otus asio), Bell's vireo (Vireo bellii), yellow warble (Dendroica petechia), and the bronzed cowbird (Molothrus aeneus). The Rio Grande canyons serve as a significant refugium for one highly endangered species, the peregrine falcon, which nests on high canyon walls and hunts for food along the riverway.

Fewer mammals than birds show a strong riparian dependence. Boeer and Schmidly (1977) documented 30 species of terrestrial mammals in riparian habitats in BBNP, but only one species (the beaver, Castor canadensis) is restricted to these areas. Major changes in the vegetation during the past 30 years, involving an increase in basal and canopy cover, have resulted in the elimination of at least one species (Dipodomys ordii) from the river corridor as well as increased abundance and distribution for two other species (Sigmodon hispidus and Peromyscus leucopus). Other mammals with a strong riparian dependence along the Rio Grande include the Pecos River muskrat (Ondatra zibethicus ripensis) and the raccoon (Procyon lotor).

HUMAN ACTIVITIES AND IMPACTS

Recreational Impact

As leisure time, personal income, mobility and population levels have increased, public agencies have sought to acquire more park and recreation areas. In addition, the private sector has created many other recreation

attractions in the Rio Grande Valley. This increase in recreation areas and their increasing use has created a complex array of problems for the various state and federal agencies entrusted with managing these resources. BBNP and ARA were acquired in 1944 and 1968, respectively. Figures provided by the NPS show that park use has increased steadily each year except during the 1974 oil embargo. During 1977, for example, total visitation to BBNP and ARA was 402,433 and 993,577, respectively. Breaking this visitation data down, we can determine how much is related to the river (or reservoir) and riparian habitats. For example, in 1975 the Rio Grande accounted for 49% of the total backcountry use (in man-days) in BBNP: 25% of this use was float trips on the Rio Grande and 24% involved camping at primitive sites along the River Road (Ditton et al., 1976). Additionally, we find that two of the three developed camping areas maintained by the NPS are located in the riparian zone. Although visitation at Amistad exceeds BBNP visitation as reported by the NPS, we found that much of this visitation at Amistad was of an overnight or "pass through" variety. Also we found that visitation to private facilities like motels and campgrounds greatly exceeded public campground visitation in the area. Camping activity at ARA is concentrated, however, at one major campground called Governor's Landing.

Schmidly, et al. (1976) used correlation analysis to investigate the relationships among human use, impacts, and biological parameters (rodent fauna and vegetation) at 18 riparian sites in BBNP. Their results revealed a positive and significant relationship between total subjective human impact ratings and annual camping use by site (in man-days). Similarly, they noted that human impacts were more pronounced in those riparian areas where access was most convenient. The extent of human impact, however, did not correlate significantly with rodent densities at 18 sampling sites. Thus, correlation analysis revealed that the sites have been impacted as a result of recreational use, but not to the point where ecological conditions, as indicated by the biological health of the rodent fauna, were in jeopardy (Schmidly et al., 1976). At ARA rodent faunas were compared between an overnight campground (Governor's Landing), and an unused control site (Schmidly and Ditton, 1979). Results revealed that total rodent densities were higher at the campground than at the unused control site, although some differences in the densities of individual species were apparent between the two study sites. These differences were probably related to microhabitat differences at the two study sites rather than any component of human impact.

Some possible recreational impacts on vegetation in riparian habitats include the following (after Settergren, 1977): (1) mechanical injury to trees on heavily used areas; (2) total elimination of trees in the younger age classes (seedlings and saplings) which results in a reduction in understory vegetation; and (3) trampling which results in the reduction in the native ground cover both in amount and the number of species represented. Examples of a few kinds of these impacts were observed in our studies at BBNP and ARA. Mechanical injury to trees (such as wood cutting) was observed at several camping sites in BBNP. Furthermore, the occurrence of trees was negatively and significantly correlated with human impact, indicating that as impact increases the frequency of trees (especially the smaller seedlings and saplings) decreases (Schmidly et al., 1976). Our observations at an overnight campground at ARA indicated that recreationists did not use the entire site uniformly. Rather, they tended to congregate at and move along specific sites and routes, such as picnic benches, sanitary facilities, and the straight-line paths between. The impact of use on the vegetation was almost exclusively limited to these obviously impacted locations. Assessment of vegetation at random points throughout the campground did not reveal any significant differences in ground cover (grasses, forbs, and shrubs) between the campground and an unimpacted control site.

Another aspect of recreational use which potentially could impact some vertebrates living in riparian habitats is hunting and trapping. Several game or fur-bearing animals exist along the Rio Grande in western Texas and their preferred habitats include riparian vegetation. These include the white-winged dove (Zenaida asiatica), Pecos River muskrat (Ondatra zibethicus ripensis), and the white-tailed deer (Odocoileus virginianus).

The riparian zones along the Rio Grande provide some of the most stable known remaining habitat for white-winged dove, and it is important that hunting be carefully regulated in these habitats to insure that these birds are not seriously depleted. The drainage ditches along the Rio Grande near El Paso represent the last stronghold of the Pecos River muskrat in western Texas. This subspecies is now extinct from other areas along the Rio Grande and the Pecos River where it formerly occurred. The following is the muskrat catch by year during a five-year period for one trapper in El Paso County: 1970, 1200 muskrats; 1971, 1200; 1972, 1400; 1973, 700; and 1974, 936 (Schmidly, 1977).

High trapping pressure could eventually threaten the existence of the muskrat in the riparian habitats around El Paso.

White-tailed deer are the most common and important game animal at ARA. Evidence suggests that these deer have increased in numbers with the development of a weed-infested, flood-zone type of riparian vegetation which has developed since the construction of Amistad Dam. The population size of white-tails in this habitat is comparable to other areas in Val Verde County and hunting pressures presently are not seriously depleting the population (Ditton and Schmidly, 1977).

Livestock Impacts

The implications of our research at BBNP and ARA are that overgrazing by domestic livestock (particularly cattle) have had a much more devastating effect on vegetation and vertebrate populations than have recreational impacts. Cattle are attracted to these riparian zones because they prefer the quality and variety of forage available which, because of its moisture content, is higher in palatability (Ames, 1977). The behavior of livestock as compared to that of human users also must be considered. As mentioned earlier, people do not use a campsite uniformly but tend to restrict their activities to well defined trails, showing an obvious reluctance to pioneer new routes through unknown territory. Cattle, on the other hand, do not restrict their movements to predefined paths, and they tend to exert a more generalized disturbance on the ecosystem.

The situation relative to grazing in BBNP has changed since the establishement of the park in 1942. Early accounts (Taylor et al., 1944; Sperry, 1938) describe the vegetation along the river as open and severely overgrazed. However, since ranching activities ceased at the inception of the park, plant densities have increased greatly so that mesquite forests now occur where the river bottom was once open and sparsely vegetated. Extensive fields of grass also occur today at sites which formerly were cultivated and farmed. The increase of grasses in BBNP over the last 30 years has provided forage that is not available in the same quantity or quality across the river in Mexico. As a result, trespass livestock from Mexico have been invading the riparian corridor in increasing numbers during recent years. Unlike recreational usage, grazing by trespass livestock is a constant feature of almost all riparian sites and it not confined to one particular region or section of the river. Should this grazing activity continue to increase, it could have dangerous repercussions on the existing vegetation of the riparian corridor. Hence, dealing with the livestock problem may prove more difficult for park managers than dealing with recreational use and impacts which tend to be concentrated in some areas and virtually absent in others.

Overgrazing by domestic livestock has been prevalent in the Amistad region for the past 100 years, and only with the establishment of the recreation area in 1968 have federal lands been protected from overuse by grazing cattle. This protection is not complete, however, as fences commonly are destroyed and livestock wander onto federally protected lands. We evaluated livestock impacts in the lakeshore habitats of ARA by comparing the results of mammalian and vegetation studies at two study sites, only one of which has not been grazed for over 10 years and other which has received continuous grazing pressure (Schmidly and Ditton, 1979).

In comparing the grazed and ungrazed study sites, some marked differences were noted in the mammalian faunas, especially of rodents. These differences in species composition as well as density. The rodent fauna on the grazed site was composed primarily of heteromyid rodents (65.8% of the total catch), whereas this kind of rodents was rare on the ungrazed site (1.4% of the total catch). Cricetid rodents (primarily Peromyscus) dominated the total catch on the ungrazed site. Capture frequencies were over four times greater on the ungrazed than the grazed site, reflecting the higher density of rodents on the former area. Jackrabbits were commonly observed on the grazed site but only rarely seen on the ungrazed area. The situation was just the opposite with respect to cottontail rabbits; these lagomorphs were commonly seen on the ungrazed grid but they were rare on the grazed grid.

The differences in species composition and density of mammals between the grazed and ungrazed sites at ARA are understandable in light of differences in vegetative cover between the two study areas. In general, heteromyid rodents prefer habitats with sparse ground cover in contrast to cricetid rodents which favor situations with thicker and denser vegetation. The amount of vegetative cover available on the grazed site was was less than on the ungrazed site and average total cover between the two areas differed by almost seven percent. Thus, the more open terrain on the grazed site was suitable for hetermyid rather than cricetid rodents. Similarly, cottontails prefer areas

with a thicker, grassy vegetation, and this habitat preference ecologically separates them from jack-rabbits.

Impact of Amistad Dam

Amistad Recreation Area was created in 1968 and is located in Val Verde County in southwest Texas. The lake on which ARA is located was formed by the construction of Amistad Dam on the Rio Grande by the International Boundary and Water Commisssion as a cooperative undertaking between the United States and Mexico. The dam is located 12 mi upstream (northwest) of Del Rio, Texas; it is situated on the Rio Grande about 1 mi below the mouth of the Devils River and 33 mi below the mouth of the Pecos River. At the 1117 ft contour elevation, which is considered conservation level, the impounded water extends 74 mi up the Rio Grande, 25 mi up the Devils, and 14 mi up the Pecos River. The dam was constructed for flood control, water conservation, future electric energy production, and for recreation. The reservoir has a storage capacity of 5,666,000 acre ft, and it is the third largest man-made international lake in the world.

Environmental changes attributable to water inundation have been manifold and will take years of intensive research to completely analyze. LoBello (1976) summarized many of the obvious changes in the flora and fauna of ARA since construction of the dam in 1968 and the following discussion is a compilation of information presented by him as well as data from our research at ARA (Ditton and Schmidly, 1977).

For the most part, the original shoreline with its riparian vegetation is gone as a result of water impoundment. In a few places riparian plants such as cattails and willows are making a slow comeback. However, without the floodplain soils, complete recovery of the riparian vegetation seems unlikely.

Local disjunct populations of two trees (the Texas pistacia, Pistacia texana, and the Chisos Oak, Quercus gravesii) have been severly impacted, if not extirpated, by reservoir inundation (D. Riskund, personal communication). Riparian habitat is still evident below the dam and along the Rio Grande just south of Langtry (where the impounded water of the reservoir reaches its western-most limits), and it serves as a dramatic contrast to the rest of the reservoir. The most common plants of the pre-reservoir riparian association include scattered stands of common reed (Phragmites communis), an abundance of common cattail (Typha latifolia), a great abundance of tobacco tree (Nicotiana glauca), and some mesquite (Prosopis glandulosa), willow (Salix sp.) and salt cedar (Tamarix gallica).

A distinct flood-zone vegetation area has developed along the shoreline of the reservoir as a result of periodic water level fluctuations. Because the water level of the reservoir is always fluctuating, the size of this flood-zone also fluctuates. The flood zone vegetation includes: willow, scattered stands of cattail, dead brush (Acacia rigidula, Leucophyllum frutescens, Prosopis glandulosa), dead cacti (Opuntia engelmannii, O. grahamii), and a variety of annual weeds (Conyza canadensis, Croton sp., Cyperus sp., Pluchea sp., Henelium sp., Polygonum sp., and Cenchrus sp.). These annuals and other weeds quickly cover the flood-zone areas, showing dense development from mid-summer to fall.

The impacts of land flooding have been catastrophic to many vertebrates occurring in the Amistad region. Sixty-five species of fish were known to occur historically in this region and, of these, 16 may now be displaced or eliminated in the area due to changes in vegetation and water depth resulting from inundation. At least one fish species Gambusia amistadensis, is now extinct in the wild as a direct result of the filling of the reservoir. The other 15 species are known only from surveys conducted in the early 1950's and 1960's.

Among reptiles and amphibians, only those species directly associated with sandy riparian areas have been seriously affected by the reservoirs inundation. Examples of species which have suffered as a result of inundation of their preferred habitat and which now are either absent or rare in the Amistad region include the following: barking frog (Hylactophryne augusti), two species of aquatic turtles (Chrysemys scripta and Trionyx spiniferus), the marbled whip-tailed lizard (Cnemidophoris tigris), the Texas spiny lizard (Sceloprus olivaceus), rough green snake (Opheodrys aestivous), and the copperhead (Agkistrodon contortrix).

The loss of riparian vegetation undoubtedly has had a profound effect on bird populations which use this vegetative zone for nesting, foraging, roosting and cover during migration. At least two small mammals, the muskrat (Ondatra zibethicus ripensis) and the

Texas pocket gopher (Geomys personatus), have become extinct in the Amistad area since reservoir inundation was initiated. Bailey (1905) reported the Texas pocket gopher from sandy soils along the Rio Grande at Del Rio and at the mouth of Sycamore Creek. Flooding of the reservoir undoubtedly destroyed the deep sandy soils along the river systems which constitute the favored habitat for this gopher. Similarly, it is doubtful that the muskrat still occurs at ARA. Bailey (1905) found it "in suitable places along the whole length of the Pecos River and on some of the tributaries and along the Rio Grande near the mouth of the Pecos." Since muskrats are directly associated with marsh areas, it would seem that the inundated water of Amistad would have largely eliminated this rodent from the area. Three other mammals (the beaver, Castor canadensis; fox squirrel, Sciurus niger; and opossum, Didelphis virgiana) have declined drastically in numbers since construction of the dam.

Reservoir inundation has not had a totally negative impact on the vertebrate fauna of the Amistad region. A variety of vertebrates living along the river and stream courses during pre-reservoir days have survived in the altered flood-zone type of riparian vegetation, and many of these species are seemingly more abundant today than they were prior to construction of the dam. Populations of the cotton rat (Sigmodon hispidus), and the white-tailed deer (Odocoileus virginianus) have increased with the establishment of a weed infested flood-zone habitat. Other mammals which should benefit from the increase in shoreline and general change in water character include the nutria (Myocaster coypus) and the raccoon (Procyon lotor).

Birds are the vertebrate group which have probably benefited most from usage of the lake. Waterfowl, shorebirds, and wading birds undoubtedly use these areas for drinking and feeding purposes. Predatory birds, including hawks and owls, use the flood-zone areas for interim feeding purposes. At least one species, the cliff swallow (Petrochelidon pyrrhonota) definitely uses the flood-zone as a nesting aid by gathering mud along the shoreline.

Water Diversion and Stream Channelization

Some of the most extensively impacted regions of the Rio Grande occur between Fort Quitman and Presidio, Texas, where much of the stream is dry and contains water only during periods of severe flooding. The channel of the river in this region has seriously deteriorated since the late 1940's because most of the water flow has been diverted due to regulation by upstream reservoirs or water diversion for irrigation around El Paso. Consequently, the river has not been able to naturally maintain its channel clear of sediments and vegetation. Ecological studies have shown that the quality of the floodplain habitat for wildlife and native plants has been declining in recent years with the deteriorating channel. Salt cedar continues to spread rapidly over the floodplain and replace the natural vegetation (cottonwoods and willows). This is causing a continuing serious reduction in the food and cover for wildlife so that the river is becoming poor habitat for riparian organisms, as the following examples illustrate. The Mexican beaver (Castor canadensis mexicanus), which is morphologically and behaviorally distinct from other Texas beavers (Schmidly, 1977), was once common along this stretch of the river with specimens having been recorded throughout El Paso and Hudspeth counties. However, a recent survey turned up evidence of beaver sign at only three localities, indicating that this mammal is less common today than it was in the past (Engel-Wilson and Ohmart, 1978). The density and diversity of fish is low along this stretch of the Rio Grande and Hubbs et al. (1977) attribute this to the high salinity of the water and to periodic drought conditions which restrict the aquatic fauna to pools.

The United States and Mexico in 1970 signed a treaty agreeing to resolve their pending boundary location differences by restoring and preserving the character of the Rio Grande as the international boundary. In the same treaty, the two governments agreed to reduce to a minimum the shifting of the channel of the River. As part of the implimentation of this treaty, the United States section of the International Boundary and Water Commission has proposed to channelize and restore a 200 mi reach of the international boundary from a point 10 mi downstream from Fort Quitman to a point about 6 mi upstream from Presidio, Texas (Draft Environmental Impact Statement, DEIS, 1978). Further, as a part of the restoration, it has been recommended that a cleared passageway be provided along each side of the channel to facilitate the flow of floodwaters along the alignment of the channel and to further minimize shifting of the river. No channel excavation work is planned for the narrow canyon sections where the river is naturally confined and will not change its course. Materials excavated from the

channel will be spoiled on mounds of debris in areas of little or no wildlife value, and these spoil areas will be seeded with native plants. No concrete works will be constructed in or along the channel. A 25 foot wide fringe of existing trees will be maintained between each side of the river and the passageway. This fringe will be left along the channel bank to retain its wildlife benefits and to help stabilize the channel. Also, cottonwoods and other select mature trees will not be removed from the passageway.

Extensive surveys of the flora and fauna have shown this proposal to be beneficial to most riparian wildlife (Engel-Wilson and Ohmart, 1978). The trend towards increased soil salinity and spread of salt cedars would be generally curtailed, and, in some areas, improvements in soil salinity should occur incident to better drainage of floodwaters from the floodplain of the channel. This would improve the habitat for wildlife and should provide improved water areas for wildlife (DEIS, 1978).

Other Impacts

Included in this category are localized human activities which create indirect impacts not characteristic of the entire river system. The introduction of exotic plants and fishes is one such activity which, in the long run, could have serious ramifications for the native flora and fauna of the Rio Grande. Significant vegetation changes have occurred in the riparian habitats of the Rio Grande over the past 30 years. The major change is associated with the tremendous increase of salt cedar (Tamarix) which appears to be replacing native cottonwood and willow trees at many places along the river. Research at other riparian habitats (i.e., lower Colorado River) has demonstrated that the salt cedar community supports fewer birds than native communities and that the breeding populations of many birds may be reduced or extirpated as a result of the loss of native vegetation (Anderson et al., 1977).

The introduction of exotic fishes, especially bait minnows, is a serious problem at certain areas along the Rio Grande where exotics seem to be increasing in numbers and replacing native fishes. For example, Hubbs and Wauer (1973) record that introduced Fundulus kansae may compete with and reduce population densities of native Campostoma ornatum in Tornillo Creek in BBNP. The latter species is known in the United States only from a few scattered tributaries along the Rio Grande.

Land clearing in riparian habitat for purposes of cultivation has been extensive around El Paso and Presidio, which are the main agricultural centers along the Rio Grande in western Texas. At both of these places, pesticide applications have been used extensively to control insect pests, and there is some concern that pesticide buildups could detrimentally affect organisms living in these areas.

Applegate et al. (1971) studied the effects of distribution of DDT and methyl parathion from cotton fields to the surrounding area within a 30 mi radius of Presidio, Texas. Although most of their sampling sites were located in cotton fields or desert habitats around Presidio, at least two of their sites were situated in riparian areas. Therefore, their conclusions are applicable to riparian as well as desert habitats. These authors determined the concentrations and distributions of the insecticides in birds, lizards, rodents, and jackrabbits as well as several kinds of plants. Although there did not appear to be any direct insecticide-mortality relationship, there may have been an indirect relationship. Most insecticides entered the fauna via the food and were transported to muscle tissue and fat, including lipid materials in the brain. The insecticides in the brain may have led either to impaired motor ability or to behavioral change. Rodents carrying high body burdens of methyl parathion were recaptured more often than rodents carrying less residue. The jackrabbit population did not have normally distributed age-classes, and juveniles with high insecticide concentrations died. Insecticide uptake by plants was closely correlated with rainfall and showed little correlation with insecticide applications to cotton plants. Fortunately, Applegate, et al. (1971) found that pesticides break down very rapidly in the Chihuahuan Desert habitat. They attributed this rapid break down to high soil temperature, high ultraviolet radiation, and the alkaline nature of the soil.

Holmes (1970) found dangerously high levels of chlorinated hydrocarbons in fat samples of muskrat from El Paso County. During irrigation seasons, canal water is used to flood cultivated fields with the excess water flowing into the drains. This excess runoff contains in solution remnants of the chemicals, defoliants, and pesticides used to treat crops. Human households in the area also have sewage systems which dump into the drainage ditches. According to Holmes (1970), the situation caused by chemical pollution plus high trapping pressure

(discussed earlier) could seriously threaten the existence of muskrat around El Paso.

SUMMARY

The riparian zone of the Rio Grande in west Texas (from El Paso to Del Rio) is a very important area influencing the habitat of many vertebrates. Several vertebrate species are present that are absent or rare elsewhere, and numerous species utilize the river corridor as routes through inhospitable habitat. Many of man's activities affect the riparian zone to varying degrees. We consider reservoir inundation, water diversion, and livestock grazing to be among the most severe disturbances. As a result of these activities, the character of the river in west Texas has changed drastically during the past 100 years. The pattern of change is reminescent of that occurring along other rivers in the Southwest, as for example the Colorado River (discussed by Ohmart et al., 1977).

There are virtually no gallery forests remaining between El Paso and Presidio; a few isolated cottonwoods remain along ditches or canals apart from the tall and dense salt cedar forets. The most pristine and unaltered section of the river begins at the confluence of the Rio Conchos (near Presidio) and continues downstream to BBNP and through the "lower canyons" to Langtry. Below Langtry the river has been completely altered by the construction of Amistad reservoir and the attenuate ecological changes have been catastrophic.

Can anything be done and is anything being done to prevent the further loss of the riparian resource along the Rio Grande? Just recently the portion of the river from BBNP to Langtry has been designated as a wild and scenic river which should prevent future habitat alterations. A project is currently being initiated to channelize and restore segments of the river from Fort Quitman to Presidio. Although stream channelization is often ecologically detrimental, in the case of the Rio Grande in west Texas it could have positive effects for riparian vegetation and wildlife.

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Evaluating the Effects of Habitat Alteration on Birds and Small Mammals Occupying Riparian Communities[1, 2]

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Abstract.--Birds and small mammals were censused along stream segments in Iowa, representing a range of habitats from open fields to closed-canopy woodlands. Vegetation was sampled and general habitat types identified. The reciprocal of Simpson's index was used to express breadth of habitats selected and nest-site specificity. The general application of using an index of niche breadth in conjunction with conventional plant and animal sampling techniques to assess species' susceptibility to habitat alteration is discussed.

INTRODUCTION

Riparian habitats are critical to wildlife (Holder 1969), especially in regions with intensive agriculture such as the Central Plains. Much of the non-tillable land in these areas adjoins streams and rivers, and in some instances it represents the major refuge for wildlife. Because suitable habitat is the most important factor influencing the distribution and abundance of wildlife species, a knowledge of habitat requirements can be used to predict the effects of various habitat alterations on population levels. The extent of change in community composition depends upon the specificity of each species' habitat requirements. Species with restricted habitat-usage patterns are more vulnerable to changes in land-use practices than those occupying a wider variety of environments.

The objective of this report is to propose one means of evaluating the effects of various habitat alterations on bird and small-mammal communities. This method employs conventional plant and animal field sampling techniques in conjunction with an index of niche breadth.

STUDY AREA AND METHODS

Guthrie County, Iowa was selected as the study area because of the availability of a variety of riparian habitats. Twenty-eight study plots were established along segments of Brushy Creek, Beaver Creek, and the Middle and South Racoon Rivers; representing a range of riparian habitats from open fields to closed-canopy woodlands. Five plots were located along channelized streams.

Bird census plots consisted of transects paralleling the stream channel, with the first transect 25 m from the stream edge and successive transects 50 m apart. Flagged markers were placed at 25-m intervals along each transect. Small-mammal trapping stations were located 12.5 m apart, also along transects paralleling the stream channel that began 12.5 m from the stream edge. Maximum transect length for both bird and mammal plots was 500 m; the length and number of transects were determined by the

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[2]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Pine Mountain, Georgia, December 11-13, 1978.

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extent of relatively homogeneous habitat.

Frequency of all plant species occurring within and(or) above a 1-m^2 quadrat, positioned at each bird census grid point, was recorded; in addition, saplings and trees were measured using the point-centered quarter method (Cottam and Curtis 1956). At each mammal trapping station, the percentage cover of all plant species occurring within a 1-m^2 quadrat was estimated visually. Vegetation measurements were made from June through August.

General habitat types were identified by reciprocal averaging ordination (Hill 1973) of the plant species frequencies and coverages on the bird and small-mammal study plots, respectively. Six general habitats were represented on the bird census plots: herbaceous, savannah, scrub, wooded edge, and floodplain and upland woodlands. The general habitat categories on the small-mammal study plots were: channelized; wet and dry floodplains; and heavily grazed, lightly grazed, and ungrazed uplands.

Breeding birds were censused on all plots during the early morning from mid-April to mid-July using the mapping method (Kendeigh 1944). During a census, transect lines were followed until the plot had been completely traversed. Observations of resident birds 25 m on either side of each transect were recorded on grid maps of the plots. Plots were censused on a rotational schedule until each had been covered 12 times. The number of times each bird species was observed in the general habitat types was determined from the census observations and expressed per unit area.

Most nests were located either by observing breeding behavior or by searching suitable vegetation. Additional nests were found incidental to censusing. For open-nesting species, the life-form of the plant providing nest support (or cover, in the case of ground nests) was categorized as grass, forb, shrub, deciduous sapling (<3 m tall), deciduous tree (>3 m tall), or evergreen tree. Cavity-nest support types were classified as snag, dead limb, or live tree.

Small mammals were trapped on all plots from May through August. Each study plot was trapped for four consecutive days and nights using Sherman live-traps. Traps were checked in early morning and afternoon, and all captured animals were toe-clipped for future identification. Following the live-trap sequence, each plot was trapped with museum special snap-traps for four consecutive days and nights. Population densities were estimated from live-trap data using the method described by Marten (1970). Populations of some small-mammal species could not be estimated accurately from live-trap data because of low susceptibility to, or complete avoidance of, live-traps. For these species, a relative abundance index (catch/effort) was calculated from snap-trap data (Nelson and Clark 1973).

The reciprocal of Simpson's index ($1/\Sigma P_i{}^2$, where P_i = the proportion of the total sample in the i^{th} group) was used as an expression of niche breadth across the resource categories being analyzed (Whittaker and Levin 1975:169). Index values were calculated for habitat selection of the bird and small-mammal species based upon their abundances in the general habitat types, and for nest-site selection of open-nesting and cavity-nesting bird species based upon frequency of use of the various vegetation life-forms and cavity-nest support types, respectively. Species with broader niches (higher index values) were assumed to be tolerant of a greater variety of habitat alterations than those with narrower niches. Hereafter, the index will be referred to as the tolerance index.

RESULTS AND DISCUSSION

Habitat Selection by Birds

Table 1 presents the distribution of breeding-bird observations among the six general habitat types. Although the original study included data for 52 different species, only a representative sample of species will be considered in this report to illustrate the application of the method. The frequency of observation values were considered to represent intensity of habitat use. The habitat(s) receiving the most frequent use by a species was(were) assumed to be preferred by that species. Species with low tolerance indices are restricted to fewer habitats and(or) utilize their selected habitats less evenly. Such species would be affected more adversely by loss of their preferred habitat than those with higher index values that more regularly use alternative habitats. Three general levels of tolerance to habitat alteration will be discussed: intolerant, moderately tolerant, and tolerant.

Intolerant species have the most restricted habitat utilization patterns and can be regarded as habitat specialists. Thus, the ovenbird (*Seiurus aurocapillus*) and western meadowlark (*Sturnella neglecta*) would be considered intolerant species, although each specializes on a different habitat type (woodland and treeless herbaceous communities, respectively). Extensive reduction in tree cover would eliminate the ovenbird while favoring the establishment of western meadowlarks. The reverse would be true if a forest canopy were allowed to develop through community

Table 1.--Distribution of breeding bird observations among the general habitat types (expressed as the number of observations per ha per 12 censuses) and general habitat tolerance indices for representative open-nesting and cavity-nesting species

	General habitat types						
	Herbaceous	Savannah	Scrub	Wooded edge	Floodplain woodland	Upland woodland	Tolerance Index
Intolerant species							
Ovenbird				0.2	0.1	1.5	1.41
Western meadowlark	6.2			2.4			1.67
Moderately tolerant species							
Dickcissel	4.8			5.4	0.8	0.1	2.33
Field sparrow	0.4			1.4	Tr[1]	1.8	2.42
Red-winged blackbird	14.3	0.4	5.8	5.4	3.1	0.1	3.06
Mourning dove	0.2		1.0	0.9	1.3	3.0	3.27
Common yellowthroat	4.5		2.1	11.0	7.7	0.7	3.29
Tolerant species							
Blue jay	0.3	1.4	0.5	1.8	3.3	4.6	3.73
Song sparrow	6.5	2.4	7.6	10.9	2.2	0.2	3.87
Great crested flycatcher		5.3	5.0	0.9	1.9	3.3	3.93
Black-capped chickadee		2.0	7.6	2.4	7.5	4.6	4.01
House wren	0.9	5.8	21.0	11.6	34.5	21.3	4.01
Eastern wood pewee		3.3	2.9	0.3	3.1	3.8	4.13
Downy woodpecker	0.1	0.9	3.2	5.2	6.0	3.5	4.14
Gray catbird	0.3	4.7	8.2	5.9	14.5	7.4	4.32
Cardinal	0.2	4.9	13.7	6.0	11.2	7.6	4.41
Common flicker	0.4	0.7	1.6	1.8	1.7	2.7	4.76
Brown-headed cowbird	3.4	4.9	7.9	10.7	5.7	3.9	5.12

[1]Tr = <0.05

succession. Species with low tolerance indices and which specialize in habitat that is threatened by contemporary or proposed land-use practices should be major focal points of concern.

Moderately tolerant species occupy a greater variety of habitats than intolerant species, but they still show relatively strong habitat preferences. For example, the dickcissel (*Spiza americana*) prefers herbaceous and wooded-edge habitats; the field sparrow (*Spizella pusilla*), wooded edge and upland woodland; and the common yellowthroat (*Geothlypis trichas*), wooded edge and floodplain woodland. Although the three species utilize four of the six habitat types in common, land-management practices aimed at reducing particular cover types would affect the species differentially because of their selective preferences.

Tolerant species are the most generalized in their habitat choice and, because of their ubiquity, usually would be least influenced by habitat alteration. Most of these species are found in all habitat types. Some interesting comparisons can be made among species within this group. The blue jay (*Cyanocitta cristata*) and song sparrow (*Melospiza melodia*) have nearly equal tolerance indices, but their habitat preferences differ markedly. The former prefers woodland communities and the latter, open habitats. Each would be affected differently by habitat alteration, depending upon whether it

resulted in an increase or reduction in tree coverage. The overall impact, however, would be less extreme than that for intolerant or moderately tolerant species, because habitat selection by tolerant species is more extensive and uniform. House wrens (*Troglodytes aedon*) and downy woodpeckers (*Picoides pubescens*) are nearly identical in habitat-usage patterns but they differ noticeably in relative abundance. The differences in population densities of the two species could result in differential vulnerability to various land-use practices despite the similarities in habitat preference. The largest index value was recorded for the brown-headed cowbird (*Molothrus ater*), a species well known for the diversity of hosts it parasitizes. Not only was it present in all habitats, but it also had the most even distribution of observations among the habitat types of the species studied. The cowbird probably would be little affected by most changes in land-use practices.

Nest-Site Selection by Birds

Nest-site availability is an important prerequisite in habitat selection by birds (Hilden 1965, Verner 1975). Birds appear to select nest sites on the basis of substrate structure rather than plant species composition (Beecher 1942). Accordingly, the variety of vegetation life-forms (representing substrate structure) utilized by a species for nest support should indicate its adaptability to changes in habitat structure. As species become more generalized in their selection of nesting substrates, factors other than nest-site availability probably become more important in habitat selection.

Open-Nesting Species

Certain species restrict nest placement essentially to a single substrate type. These birds are specialized in their selection of nesting sites and generally would be intolerant of a reduction in their preferred nesting substrate. In this category are the eastern wood pewee (*Contopus virens*) and blue jay, that utilize deciduous trees, and the common yellowthroat, nesting in grass (Table 2). Habitat management practices that remove or drastically alter these preferred substrates would eliminate requisite nest cover, and consequently, would make an area unsuitable for breeding populations.

A second category of species may show preferences for a particular nesting substrate, but also utilize alternative nesting sites. These species can persist in a habitat after alteration of their preferred nesting substrate by shifting to alternative life-forms; however, nesting densities may decline and competition for these alternative nest sites could become more intense. The gray catbird (*Dumatella carolinensis*) would be affected adversely by the loss of shrubs and the mourning dove (*Zenaida macroura*) by the loss of deciduous trees, but both could maintain breeding populations by shifting nest placement to other woody vegetation.

Table 2.--Distribution of nests among various support life-forms and life-form tolerance indices for representative open-nesting species

Species	Life-Forms						Tolerance index
	Grass	Forb	Shrub	Deciduous sapling	Deciduous tree	Evergreen tree	
Eastern wood pewee					21		1.00
Blue jay					32	2	1.12
Common yellowthroat	11		1				1.18
Song sparrow	4	8					1.79
Gray catbird			66	10	13	3	1.83
Field sparrow		1	6			2	1.98
Mourning dove			7	6	39	6	2.03
Cardinal			38	15	15	8	2.96
Dickcissel	3	4	1	1			3.00
Red-winged blackbird	15	6	6	3	1		3.12

The importance of adequate and representative sampling is illustrated by the distribution of the located field sparrow nests among the various support life-forms. All but one nest was found in woody vegetation, and none were discovered in grass. Also, the sample size was relatively small (9 nests). According to other studies (Walkinshaw 1968, Best 1978), grass cover is a major nesting substrate used by field sparrows, particularly early in the breeding season. The absence of grass-supported nests in our sample could be attributed to regional differences in available habitat or nesting requirements, but grass nests also are more difficult to locate by searching vegetation and likely were under represented in the relatively small sample.

Some open-nesting species are generalized in their selection of nesting substrates. These species would be relatively tolerant of habitat alterations. Of the three most tolerant species listed in Table 2, only the cardinal (*Cardinalis cardinalis*) restricts nesting to woody substrates, but it utilizes all woody life-forms with relatively high regularity. The dickcissel and red-winged blackbird (*Agelaius phoeniceus*) use both herbaceous and woody vegetation for nest support, and the redwing, in particular, appears to be a nest-site generalist.

Nest sites of cardinals and gray catbirds are most often associated with shrub cover, but the two species differ in their preference for (and possibly dependence upon) shrubs for nest support. Both use the same alternative life-forms for nesting, but the cardinal is more prone to do so. Consequently, management practices resulting in shrub removal probably would have a more adverse effect on catbirds than cardinals.

Patterns of nest-site and habitat selection in the eastern wood pewee are of interest because, although this species restricts nesting to a single substrate (see also Graber et al. 1974), it utilizes a relatively broad range of habitat types (Table 1). The wood pewee would be considered a nest-site specialist, but a habitat generalist. Thus, there are limitations in evaluating only general habitat selection at the exclusion of identifying more specific requisites such as nest sites, food, and protective cover from predators. In some instances, the more specific information would be needed to accurately predict the impact of a particular habitat alteration.

Cavity-Nesting Species

All cavity-nesting species are specialists in that they nest only in trees (artificial nest-boxes excepted). Removal of snags from wooded habitats would drastically reduce potential nest sites for both primary (cavity excavating) and secondary cavity-nesters, although both can use dead limbs of live trees or live trees as alternatives (Table 3).

Table 3.--Distribution of nests among various support types and support type tolerance indices for representative cavity-nesting species

Species	Support types			Tolerance index
	Snag	Dead Limb	Live Tree	
Primary cavity-nesters				
Downy woodpecker	25	3	2	1.41
Common flicker	20	3	8	2.03
Secondary cavity-nesters				
Black-capped chickadee	23	1	1	1.17
House wren	61	19	2	1.64
Great crested flycatcher	5	3	5	2.86

Of the representative species listed in Table 3, the black-capped chickadee (*Parus atricapillus*) is the most dependent on snags for nest sites and it also has the lowest tolerance index. An interesting comparison can be made between chickadees and house wrens. The two species have identical tolerance indices for general habitat selection (Table 1), but because the house wren is less restrictive in choosing nest cavities, it probably would be less vulnerable to habitat alterations, particularly those involving snag removal. The great crested flycatcher (*Myiarchus crinitus*) is the most generalized cavity-nester. It selects dead limbs and live trees as nest sites more frequently than snags. In general, the tolerance indices for all cavity-nesting species increase with a decrease in dependence on snags for nest sites. Ignoring snag densities in evaluating general habitat quality could lead to erroneous conclusions concerning the habitat suitability for cavity-nesters.

Habitat Selection by Small Mammals

Although small-mammal species abundances were estimated using two different methods, their tolerance indices can still be compared because they are based upon proportions and not absolute values. Of the representative small mammals, the two species most intolerant of habitat change restrict their activities primarily to the two

most disturbed habitat types: heavily-grazed upland and channelized (Table 4). The 13-lined ground squirrel (*Spermophilus tridecemlineatus*) prefers the former and the prairie deer mouse (*Peromyscus maniculatus bairdii*), the latter. Usages are minimal (or nonexistent) in the other more "natural" habitat types with better-developed tree canopies. Timber removal, grazing, and stream channelization were the prevailing habitat alterations in this study. These land-use practices convert woodlands into open communities dominated by herbaceous vegetation. The intolerant species specialize on these altered habitats and, consequently, have profited the most. Thus, a given land-use practice may actually benefit a relatively "intolerant" species if by chance the disturbance increases availability of its preferred habitat. Other habitat changes, however, such as those resulting from invasion of trees and shrubs and(or) discontinuance of livestock grazing, would severely limit the intolerant small-mammal species because of their restricted habitat preferences.

The masked and short-tailed shrews (*Sorex cinereus* and *Blarina brevicauda*) are considered to be moderately tolerant of habitat alteration, primarily because they use a wider range of habitats than the intolerant species. Moderately tolerant species also exhibit habitat preferences but these are less well defined. Eastern chipmunk (*Tamias striatus*) densities were fairly uniform in five of the six habitat types. This species is relatively tolerant of most forest disturbances, but complete timber removal (as was the case in channelized habitats) would eliminate populations. The white-footed mouse (*Peromyscus leucopus*) was the only small-mammal species that occurred in all general habitat types in our study. The ubiquity of this species has been documented elsewhere (e.g., Geluso 1971, Krull and Bryant 1972), and these mice do not appear restricted severely by habitat requirements. In contrast to its intolerant congener, the prairie deer mouse, grazing and channelization are the most detrimental land-use practices for the white-footed mouse, although it occurs in relatively high densities even in areas subjected to these disturbances.

CONCLUSIONS AND RECOMMENDATIONS

Tolerance indices provide estimates of niche breadth that are useful when evaluating effects of habitat alteration. An awareness of the habitat types that most often result from contemporary land-use practices is necessary in selecting field sampling sites. This assures that the information obtained adequately represents habitat availability, and thus, maximizes the value of the data in predicting responses to habitat alteration. Inadequate sampling of habitats could create results

Table 4.--Abundances[1] in the general habitat types and general habitat tolerance indices for representative small-mammal species

	General habitat types						
	Channelized	Wet floodplain	Dry floodplain	Heavily-grazed upland	Lightly-grazed upland	Ungrazed upland	Tolerance index
Intolerant species							
13-lined ground squirrel	0.27			2.11			1.24
Prairie deer mouse	17.65	1.82		4.41			1.70
Moderately tolerant species							
Masked shrew	0.30	0.50			0.14	0.04	2.65
Short-tailed shrew	1.48	1.23		0.28	0.11	0.11	2.73
Tolerant species							
Eastern chipmunk		4.59	11.86	10.72	14.43	10.64	4.48
White-footed mouse	29.95	85.66	80.79	35.26	47.82	49.43	5.12

[1]Estimated densities per ha for 13-lined ground squirrels, prairie deer mice, eastern chipmunks, and white-footed mice; relative abundance indices (percent trapping success per 100 trapping units) for masked and short-tailed shrews.

suggesting a restriction in habitat selection that is artifactual rather than representing the actual diversity of environments selected. The results we have reported are most applicable to species occupying riparian habitats of the Central Plains. Application to other geographical areas or habitats should be made with caution.

Tolerance indices obtained from extensive field sampling can be used to identify those species most vulnerable to current and proposed land-use practices. Once identified, these species may become the subjects of more intensive study that would be beyond the scope of a broad community survey.

One advantage of our approach is that it does not require intensive field sampling methods and it facilitates extensive sampling in a relatively short period of time. Although we determined the general habitat types using conventional plant sampling and analysis techniques (quadrat and point-centered quarter sampling; ordination analysis), broad habitat categories based upon similarities in physiognomy and plant-species composition could be determined by less rigorous plant sampling procedures or perhaps merely by qualitatively classifying cover types. Birds and small mammals could be censused using techniques other than those described in this report, and the reciprocal of Simpson's index is only one of several indices commonly used to measure niche breadth (see Whittaker and Levin 1975).

The tolerance index values are influenced by the same biases that affect census results, such as differences in bird detectability in various habitats and differential catchability among small-mammal species. Also, variable efficiency in locating nests in different substrates could lead to sample bias (e.g., field sparrow). Tolerance indices are most accurate with large sample sizes. Where sample sizes are small the indices should be interpreted with caution, because a small shift in observation distribution can alter radically the index value. Relatively uncommon or rare species are the most difficult to evaluate because the small sample sizes may not accurately represent habitat-usage patterns. Consequently, the predicted tolerances may indicate a higher level of specificity (or less likely, generality) than is actually the case. In many instances, these uncommon or rare species may be near the periphery of their range of distribution, and the habitats sampled may be only marginal. Of much greater concern are species that are rare because their optimal habitat is in short supply. These may require much more intensive study than could be accomplished by extensive faunal surveys.

This study evaluated habitat usage only during the late spring and summer periods (the breeding season in the case of birds), but easily could be expanded to include other seasons as well, with appropriately modified field sampling techniques. Community species composition varies throughout the year and should be considered. For individual species, habitat requirements and usage patterns may change with the seasons, as well as the degree of specificity in habitat selection. For example, a species may have restricted habitat-selection patterns during the breeding season but may become relatively ubiquitous at other times. Once these changes have been documented, attention could be concentrated on the life-history stages most vulnerable to environmental modifications. It is at these stages that habitat requisites are most critical and to which habitat preservation measures should be directed and intensified.

Other requirements critical to wildlife also could be considered in addition to general habitat and nesting sites; such as, structural features of the vegetation, plant-species composition, availability of food resources, and microclimatic conditions. These would provide better refinement in delimiting habitat preferences, but would require additional field-sampling time. Their inclusion would depend on the degree of precision desired in predicting responses to habitat disturbance and on man-hour and budget constraints.

Individual species may be generalized with respect to certain habitat requirements but highly specialized relative to others. The factor(s) for which selection is most restricted is(are) the most important in determining distribution and abundance. For instance, a superabundance of the appropriate general habitat is of little value during the breeding season if nesting sites are not available (e.g., cavity-nesters dependent on snags).

Care must be taken not to assume universally that species are inflexible in selecting habitats, nest sites, etc. simply because they are specialists. Some "apparent" cases of specialization could result from a superabundance of the preferred resource rather than a lack of adaptability in resource utilization. Also, altered habitats of recent origin may not have existed long enough to have allowed certain species adequate time to fully develop exploitation patterns. Despite these concerns, inflexibility and specialization probably are usually associated. Generalists, already predisposed to select a broad range of habitats, more likely would be expected to shift resource-usage patterns than the restricted specialists. Tolerance indices could be used to determine the adaptability of species to habitat alteration by monitoring changes in index values over extended periods of time.

Our results have dealt exclusively with non-game species of birds and mammals, but the evaluation procedure is also applicable to game species and to other taxonomic groups, with appropriately modified field-sampling techniques.

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Riparian Habitat in Channelization Projects[1]

James D. McCall[2] and Robin F. Knox[3]

Abstract.--Since 1970 construction has been completed on approximately 30 miles of PL-566 channels scattered throughout Indiana in 5 separate projects. Since 1973 a joint Memorandum of Understanding between the SCS, IDNR, and USFWS has fostered development and implementation of project features designed and installed to protect or mitigate losses of fish, wildlife and riparian habitats. Successful implementation of such features has expanded their use to channel modification caused by highway bridge construction and legal county drain maintenance.

INTRODUCTION

Sixty percent of the cropland in the State of Indiana has water related problems. Excess wetness is one of the limiting factors in crop production. To emphasize the magnitude of this wetness problem, it is significant that county governments have worked on over 36,000 miles of what we call county court ditches (legal drains) for the purpose of drainage. Most of these legal drains were dredged with little or no consideration for fish and wildlife needs.

Since 1970 SCS in Indiana has assisted local groups in completing about 25 miles of channel work for flood damage reduction and drainage. Today we will show you some of the things we have been doing to mitigate the damage caused by this work to riparian fish and wildlife resources. Twenty years ago when PL-566 channel work first started, channels were designed by engineers to move water efficiently with very little input from the biology discipline during the planning phase. Often, in level agricultural areas, most of the trees and shrubs were removed from both banks out to the crop fields. The banks were reseeded with grass to prevent bank erosion.

Since 1967 it has been the policy of SCS in Indiana to plan watershed projects with interdisciplinary input from several federal and state agencies. In Indiana, the biology team has representatives from the State Department of Natural Resources (IDNR), the U. S. Fish and Wildlife (USFWS), and the Soil Conservation Service (SCS). Since 1973 a joint Memorandum of Understanding among the three agencies has fostered development and implementation of project features designed and installed to protect or mitigate losses of fish, wildlife, and riparian habitats. Currently, the new channel modification guidelines are being implemented using the new Habitat Evaluation System (HEP). The new guidelines require that the agencies involved work together to accomplish common goals concerning fish and wildlife resources. Geologists, planning engineers, hydrologists, and economists from the SCS watershed planning staff also assist in planning.

The five projects described serve as examples of the results of multi-agency planning.

PRAIRIE CREEK (VIGO COUNTY)

Within the Prairie Creek(Vigo) Watershed in western Indiana, there was a 65-acre wet woodland that merited special considerations. Soils and geologic borings showed a very tight layer of clay near the soil surface. This in-

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[1]Paper presented at the "National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems", Callaway Gardens, Georgia, December 11-13, 1978.

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dicated that the channel could be cleaned out along one side of the woodland without draining the existing riparian wetland habitat. Before the project plan was completed, the sponsers purchased the wooded swamp to guarantee its legal protection for the life of the project. Physical protection of the swamp included levee construction and a stabilized outlet designed for passage of fish and other aquatic fauna. All planning, installation and management phases were coordinated to ensure the preservation of the riparian wetland wildlife habitat.

MIDDLE FORK OF ANDERSON RIVER (PERRY COUNTY)

Five miles of the lower end of the channel in the Middle Fork of Anderson River Watershed, in southern Indiana had adequate depth and width but the flows were restricted by fallen trees, logjams and other debris. The interdisciplinary team marked the hazardous trees and other debris to be removed. To minimize damage to living trees, the contract for the work specified that only hand tools and small machinery be used. A small boat and log skidder proved to be effective in the removal of logjams. Fallen trees were skidded up onto the bank and lodged, tied down or buried so that they would not float back into the channel. The completed job was pleasing to look at and moved the water as intended. This project was considered a success by all concerned, including local landowners, agency specialists and other observers.

Figure 1.--Completed channel work involving drift and debris removal on the Middle Fork of Anderson River in southern Indiana.

ROCK CREEK (CASS COUNTY)

The Rock Creek (Cass) Watershed flood protection channel in north central Indiana was originally constructed with a 65-foot wide flat bottom on solid limestone.

To offset the losses of fishery habitat caused by modifying this channel, a fishway of pools and riffles was constructed. The fishway was designed by the Indiana Department of Natural Resources biologists and SCS specialists working together with the local people. The pools were dug 2 1/2 to 4 feet deep and the riffles about 6 inches deep.

Field studies have shown that usage of the fishway is much better than expected. Twenty-three species of fish were found by biologists in this man-made fishway one year after completion. These species included smallmouth bass, rock bass, longear sunfish, white sucker and several kinds of darters and minnows that serve as food for bass. Only 16 species were found in the natural channel upstream from the constructed fishway. In the 3 years following, species numbers totalled 23, 22, and 23 in the constructed fishway.

Twenty-five species of fish were captured by electro-sampling during August 1978, 5 years after completion of the constructed fishway. Fish abundance generally was greater in 1978 than in previous years. Smallmouth bass ranging from 3 inches to 20 inches were found this year. The greater abundance of fish in the fishway in 1978 may have been due to construction activities upstream. Fish sampling in Rock Creek should continue on an annual basis to monitor and document any changes in stream fisheries.

ROCK CREEK (WELLS COUNTY)

Rock Creek (Wells) Watershed located in northeastern Indiana, is another place where channel work has been limited to one side only, following the existing curves of the channel. Stone was placed on lenses of unstable soil subject to erosion. Vegetation has now grown through the stone giving it a more natural appearance. A dozen different species of trees and shrubs were planted on the spoil to help offset the loss of existing vegetation.

New plantings were fenced to protect them from livestock damage. Cardinal autumn-olive was one of the wildlife fruit-producing species used in replanting spoil areas. Subsurface drains and surface water inlet structures on the non-construction side were installed with a minimum of disturbance to the existing

vegetation. Bedrock, where present, was either blasted or ripped so that the fish pools could be dug. In earth reaches, fish pools were dug deeper than the channel grade and equipped with rock deflectors.

Four years after installation, most pools have stabilized at 3 to 4 feet deep. All fish pools checked to date are functioning as intended. A few pools required additional stone riprap on the channel banks below the deflector where the soil was unstable. Fishermen have been catching both bass and channel catfish from the constructed pools.

Water coming from the Mossberg lateral in the Rock Creek (Wells) Watershed was dropped through a rock chute to prevent erosion. Riprap was applied on both banks but installed from one-side only to save existing trees on the opposite bank. The stream had adequate capacity after the drift and debris were removed with hand tools and small equipment to preserve the riparian habitat on either bank.

BUCK CREEK (HENRY COUNTY)

Buck Creek is a tributary to the Upper Big Blue River. Buck Creek's upper reaches flatten out through an area of prime farmland. Clean-out of the previously dredged channel was needed on approximately 7 miles of Buck Creek to improve drainage.

A lower reach of Buck Creek ran through a cattle feedlot. The Conservancy District leaders worked with the feedlot owner and obtained agreement to fence the cattle out of the creek. Part of the agreement was to develop a satisfactory livestock watering facility in the remaining feedlot. This was done with a minimum of cost. The creek was deepened, the feedlot was leveed and fenced and the creek banks were revegetated. Subsequent onsite inspections indicate that both water quality and riparian habitat have been improved.

Further upstream the trees were saved on one side, the spoil leveled and seeded to a grass-legume mix. Trees and shrubs were transplanted on the spoil area for wildlife habitat. Vegetation was reestablished and provided excellent cover during the first growing season. Fish pools, which were equipped with rock deflectors, continue to function well. State fishery biologists identified 11 species in 1972 prior to construction. During the year of construction only 9 species were found, but afterwards, the number of species has increased to 18. Previously uncollected species include smallmouth bass, green sided darter, silverjaw minnow, spotted bass, bluegill and longear sunfish. Deflectors have maintained the fish pools at a depth of about 3 1/2 feet over a 5-year period. Livestock are excluded from channels by fencing. In cropland, vegetative markers were placed between new tree and shrub plantings and the row crops. The markers are made of 2 inch galvanized steel pipe set in concrete. The markers protect the new plantings from accidental destruction until the shrubs grow large enough to be seen from a tractor. A heavy growth of herbaceous and woody vegetation covered the dragline spoil within one growing season. This vegetative cover acts as a filter strip to help keep sediment out of the water. Fall colors add to the beauty of this stream. Figure 2 shows a small clear stream shaded by large sycamores in a semi-natural setting with pools deep enough for fishing and a summer afternoon swim. We in the SCS think that future generations should have the option of enjoying similar opportunities.

Figure 2.--One year after dragline cleanout, trees on non-work side provide shade for constructed fish pool, while mitigative planting on disturbed banks shows partial restoration of riparian habitat.

THE UTILITY OF LEAVING SHADE TREES

There are several advantages to keeping shade over a flowing stream. An often overlooked advantage is that leaving shade can prevent willow and cottonwood from coming in at the water line and restricting channel flow. When the existing shade is removed these sun-loving species are quick to invade. It takes many years of plant succession for the plant community to return to large bottomland hardwood trees that shade out willow. Open channels

in the midwest require willow control every 2 or 3 years if they are to maintain flood flow capacity. Modern-day methods usually include chemical herbicides. However, as experienced on these projects, shade can do a very good job of controlling unwanted willow and cottonwood growth naturally, as opposed to chemical control.

In one case, mature trees were cleared from both banks by a utility company for an electric transmission line. The open sunlight triggered the invasion of willow. Willow stems of 1 to 2 inches in diameter have filled the channel. Limbs and stems interlocked so tightly that a man could not walk up the channel. These same willows restricted flow to the point that high water flowed out over the bank causing accelerated erosion. Where native hardwoods were maintained to shade this small stream, no problems have developed from willow encroachment and no chemical herbicides have been needed to control unwanted willows.

EXAMPLE OF USEFULNESS OF GOOD BIOLOGICAL REVIEW

The Upper Big Blue River Watershed is in east-central Indiana. This river, near Knightstown, is shaded and usually flows clear, with clean gravel bars. In 1963 channel enlargement was planned to reduce flood damage. However, in 1977, during intensive biological surveys initiated by SCS, a nursery colony of over 50 endangered Indiana bats (Myotis sodalis) was located at the top of the bank on the proposed construction side. Consultation with the U. S. Fish and Wildlife Service, the State Department of Natural Resources, and the Earlham College endangered species specialists, resulted in a change in plans, from channel enlargement to drift and debris removal, on about 5 miles of river.

OTHER APPLICATIONS

The various mitigative structures previously described have proved to be useful in protecting other riparian habitats in Indiana. Based on experience gained from installation of structures in the SCS projects, the Division of Fish and Wildlife has expanded their use to other types of development. In those areas where the Department of Natural Resources exercises Permit and/or other legal jurisdiction, the installation of sediment-traps, rip-rap fishpool deflectors, and one-sided channel work has become standard practice. The combined Permit Applications in Indiana for highway bridge construction, pipeline, powerline or other stream crossings, and legal drain construction, represent development that could adversely impact 25 to 35 miles of channel and associated riparian habitats per year. In many of the heavily farmed regions of the state, these riparian areas provide the only woody habitat for many of our wildlife species.

Wherever possible and feasible, the riparian habitats to be affected by development are field inspected and specific mitigative features are then made part of the Permit Approval procedures. The greatest use of SCS designed structures has been in highway bridge construction and legal drain maintenance. Although it has been difficult for some engineers and drainage boards to accept, protection of riparian habitats is an active policy of the Division of Fish and Wildlife.

Thus, the mitigative procedures developed during Soil Conservation Service planning have provided us with additional tools to insure the preservation and maintenance of Indiana's riparian habitat.

SUMMARY

In summary, techniques being used in Indiana to protect riparian vegetation and to offset or reduce the impacts of watershed projects on water quality, fish and wildlife habitat, and visual quality of the stream corridor, include the following:

1. Installation of sediment traps to prevent sediment from leaving the construction site.
2. Construction on only one side of the stream channel.
3. Handtool and small equipment removal of waterway obstructions.
4. Continuous pool-riffle fish habitat in bedrock.
5. Installation of fish pools with deflectors and constructed riffles in earth sections.
6. Woody and herbaceous vegetation plantings.
7. Maintenance of shade over water.
8. Wetland acquisition.
9. Fencing and vegetation markers.

The Effects of Channelization on Riparian Vegetation and Wildlife in South Central Oklahoma[1]

John S. Barclay[2]

Abstract.--Concern over loss of natural riparian habitats to stream alteration in the southern grasslands led to this analysis of the effects of channelization on riparian vegetation and wildlife on 2 streams in south-central Oklahoma. Since 1870, 87% of the original riparian forest, all of 54 wetlands, and 17% of the original channel lengths have been eliminated. Bird, mammal, amphibian and reptile data indicate unchannelized sites were significantly more valuable as wildlife habitats than were channelized sites. Most "old channelization" sites show no evidence of recovery comparable to the control sites as a result of intensified agriculture and hydrologic factors.

INTRODUCTION

Many streams, once heavily forested with bottomland hardwoods, extend westward from the eastern forests into the grasslands of the south-central United States. In this region, extensive forests are lacking and water is limiting, so riparian habitats are necessarily important to wildlife (National Academy of Sciences 1970). Most of the streams and associated floodplain habitats in the southern grasslands have been channelized or impoundmended for flood control and/or agricultural development.

Few quantitative evaluations of the effects of channelization or impoundment on riparian plant and animal communities have been conducted, and none were found for the southern grasslands in the available literature. Some studies have documented various aspects of Oklahoma's riparian plant ecology (Ware and Penfound 1949, Rice 1965, McLeod and McPherson 1973), but baseline information on riparian wildlife has been lacking for this region.

Concern over the continuing but unmeasured losses of riparian habitat and the lack of documentation of the effects of stream alteration on the biota provided the major impetus for this study of the impact of stream alteration on riparian vegetation and associated wildlife populations in the southern grasslands of the United States. This paper presents an overview of the channelization portion of the project. Specific objectives were to:

1. determine the composition and structure of riparian plant communities;
2. determine the species composition and relative abundance of birds, mammals, amphibians and reptiles;
3. develop the capability to predict the relationships of bird, mammal, amphibian and reptile populations to changes in the plant community that result from stream channelization;
4. interpret the results of the riparian plant and animal analyses with respect to the historical changes in riparian land use and channelization activities.

Twenty-five persons were directly involved in this study at one time or another, especially Drs. James Lewis and William Warde, and Mssrs. V. Heller, J. Brabander and J. Petranka. Each made a significant and much appreciated contribution. The many contributions of the Oklahoma Cooperative Wildlife Research Unit, Tulsa Field Office (USFWS), the Region II Office (USFWS), and the National Stream Alteration Team are gratefully acknowledged. The project was sponsored under contract number 14-16-0008-2039 with the Office of Biological Services, USFWS.

METHODS AND MATERIALS

Two southcentral Oklahoma streams, Rush

[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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Creek and Wildhorse Creek were selected from 13 potential project streams as most appropriate for the study. Selection and evaluation procedures included aerial surveys, ground reconnaissance and use of a site selection matrix analysis. Sixteen survey sites, 8 along each stream (and one additional avifauna site) were located within the 4 major land use and 3 channel types. The habitat at each site was homogeneous, at least 200 x 150 m in size, and matched by the same general land use on the opposite side of the stream. Sampling of plant and animal groups was conducted during summer 1976. Supplemental data for each group were collected periodically until June 1977.

Several procedural problems were encountered which complicated data analyses and were only partially overcome. The most critical difficulty was the lack of replicate study sites within each of the channel and land use types. However, the 2 streams used in this study contained the greatest possible array of options, since all other available channelized streams had been cleared of useable stands of original vegetation, in addition to not meeting other survey and logistics requirements. The intensity of livestock grazing was also a factor in that it probably was not uniform between sites. Grazing occurred on all but 1 cropland site and the special avifauna site, and it was assumed that the long term effects were therefore, similar.

Historical Perspective

Changes in watershed/floodplain land use which accompanied early settlement and channelization were documented at intervals from 1871 to the present. Techniques included search for and examination of miscellaneous publications and records held by the Oklahoma Historical Society, university and community libraries, the Garvin County Clerk's Office, and the U.S. Soil Conservation Service (SCS). Interviews were conducted with landowners, SCS personnel, and other persons knowledgeable about the study area.

Data on the original distribution of floodplain forests, wetlands, and stream conformations were obtained from copies of the original land survey plat maps (ca 1871). These data, plus floodplain boundaries interpolated from U.S. Geological Survey (USGS) maps, USGS floodprone area maps, and SCS watershed project maps, were transferred to USGS 7 1/2' topographic survey maps using a Bausch and Lomb Zoom Transfer Scope (ZTS). Areas of floodplain forest shown on Agricultural Stabilization and Conservation Service (ASCS) aerial photo series for 1937, 1949, 1963, and 1969 were likewise drawn on the base maps. A Numonics Model 1224 Digitizer was then used to make measurements by time period of the areas of riparian forest, wetlands and stream lengths from the plat and base maps.

Vegetation

Vegetation was sampled along 2 different 300 m transects at most sites. A "riparian zone" transect, 25 m landward from and parallel to the stream bank, was used on all but the cropland and tamegrass pasture sites. The second transect was established within the channel profile ("channel zone") when vegetation occurred in this zone, usually on a low terrace.

Forested sites were sampled using the point-center-quarter method (Cottom and Curtis 1956). Species richness, densities, importance values and diversity indices (Shannon-Weaver 1963) were derived from the data. Vertical foliage densities were derived in part by the combined use of density board measurements (Wight 1938), the Bitterlich variable-radius plotless method, and relascope readings.

The point-transect method (Levy and Madden 1933) was used for sampling the herbaceous vegatation of non-forested sites. Importance values, relative densities and frequencies were determined from the data for each species. Species diversity on each site was determined by using the percent coverage of each species. Vertical foliage densities were measured by means of the density board.

Amphibians and Reptiles

Herpetofauna data were collected on each study site by means of intensive habitat search; a baited turtle trap in the creek channel; two 8 m drift fence traps; and occasional nocturnal searches along roads in the floodplains. Herpetofauna transect lengths and the amount of search time spent on each site varied according to the extent of available habitat and vegetation diversity. Therefore the data were standardized on the basis of species and individuals encountered per 100 hrs and 100 m of survey effort. The results were summarized and compared on the basis of vegetation and channel classifications.

Birds

Observation and recording methods were similar to those described by Emlen (1971). Each 300 m x 50 m observation belt was sampled an average of 10 times during the summer 1976, and 3 times each during the fall 1976, winter 1976-77, and spring 1977. All data on parameters of the avian populations, with the exception of the life forms analysis, were calculated and compared on a seasonal basis. T-tests were used to test for significant differences between

class (channel type and land use type) means for: species diversity (Shannon and Weaver 1963), equitability coefficients (Pielou 1966), total species richness per season, mean species richness per visit, and density per visit (Sokel and Rohlf 1969). T-tests were also used to test for differences among seasons within classes for the above parameters. The similarity of species composition on all channelized sites as compared to control (unchannelized forest) sites was determined by means of a coefficient of community compositions similarity (c) (Bray and Curtis 1957, Kricher 1975). Life forms classifications fashioned after Thomas (unpublished) and Haapanen (1965) were used to relate the composition of the avian communities to vegetation structure and successional stages.

Small Mammals

Small mammal data were obtained primarily through use of the North American Standard Small Mammal Census (NAS) techniques developed by Calhoun (1948); "sign" trapping; and active den counts. Where suitable habitat was present, snap trap lines were set for 3 days within the "channel zone" as well as in the "riparian zone". All study sites were sampled once during the period 1 June - 15 August 1976. Sites W1 (unchannelized bottomland forest) and W5 (channelized bottomland forest) were also sampled once each during October 1976, February 1977 and June 1977 to monitor seasonal population levels. Quantitative analyses included use of chi-square (X^2), Mann-Whitney rank tests (nonparametric), F tests, t tests and Index of Diversity (parametric), all as found in Zar (1974).

Large Mammals

To ensure comparability, the principal survey method for large mammals involved the use of a sign-count transect (Brabander and Barclay 1977). Four fixed-width (25 m) survey lines, parallel to the stream and each other, comprised the transect whose length was determined by available habitat within each study site. Each study site was surveyed an average of 10 times during the summer 1976. Subsequent sampling was usually conducted bi-monthly and only on the survey line along the bank and along the riparian zone boundary 25 m landward. Data analysis consisted of numerical comparisons standardized on the basis of observations per 100 m of transect, by stream, species, study site, channel type and land use type. Types of sign recorded included visual observation, tracks, feeding sign, dens, scats, remains, and "other".

DESCRIPTION OF STUDY AREA

The study was conducted on selected portions of Rush Creek and Wildhorse Creek in south-central Oklahoma. The 2 streams are roughly parallel, have adjoining watersheds, and have similar physiographic characteristics. Both streams are westbank, easterly flowing tributaries of the Washita River whose basin was one of the first in the nation to be developed as an experimental upstream flood prevention project.

The Rush and Wildhorse watersheds are in the Oak & Bluestem Parkland ecoregion (Bailey 1976), which includes the Postoak-Blackjack Forest and Tallgrass Prairie associations (Duck and Fletcher, 1943). Climax dominant plant species vary considerably among range sites within the study areas. As a result of intensive grazing, poor range conditions existed on most of the study sites. The flood plains, extensively forested prior to 1900, are intensively farmed today.

The watersheds are classified as rolling-to-gently-rolling prairie and savannah (SCS 1954), with elevations above sea level ranging from 252 m to 407 m. The soils are sandy, highly erosive, and have low moisture storage capability (Gray and Galloway, 1959). Underlying geologic formations are principally sandstones and shales (SCS 1963). The characteristic climate is one of mild winters and long hot summers with an average growing season of 212 days (OWR 1968:28). The mean annual temperature is 16.7°C with monthly means ranging from 4.5°C for January to 28.1°C for August (OWRB 1968:34). Annual precipitation (87.13 cm) is exceeded by an average lake evaporation rate of 152 cm. Extremes in weather conditions are common.

Floods were a common occurrence on both streams even after channelization, but have virtually ceased since construction of 148 upstream flood control structures over the past 20 years (SCS 1977). The mean annual flow is equivalent to 122,437 kl/100 ha of watershed for Rush Creek and 79,680 kl/100 ha for Wildhorse Creek.

RESULTS

Historical Perspective

Farming and land clearing activities in the watersheds began as early as 1856 but did not intensify until 1900. Widespread abuse of upland soils furthered interest in the drainage and clearing of the bottomlands. Petitions to channelize segments of both streams, although bitterly opposed (Hedrick 1978), were initiated as early as 1919 and eventually authorized. The early channelization work by private groups

began in 1921 and the last section was completed in 1933. An additional 15.2 km middle reach segment of Wildhorse Creek was channelized between 1968 and 1971 with SCS technical assistance. The "old" channel work included dredging of new channels some distance from the old channels in the lower reaches, cutting new channels across meanders in the mid-reaches, and cutting across individual meanders especially in the upper reaches. The most recent channel work involved enlarging the original channel and bypassing some meanders.

Changes in Channel Morphology

Channelization has reduced the original (1871) combined channel lengths (200.8 km) of the 2 streams by 16.7% for a net loss of 33.6 km of aquatic ecosystem. In addition, 46% (77.5 km) of the total 167.2 km of existing channels have been channelized. Channelized segments show a combined reduction of 31.4% (35.5 km) in length in relation to the comparable 1871 portions, while unchannelized segments show a 2.1% (1.9 km) increase in length. Comparisons of 1977 channel width and depth measurements at each study site to the channelization contract specifications indicate erosion has resulted in a 500-800% increase in channel capacity since 1921-33 (Hedrick 1978:22).

Changes in Land Use

A total of 54 wetland areas, covering 725 ha as shown on the 1871 plat maps, was digitized. All of these wetlands were on the eastern two-thirds of the Rush and Wildhorse floodplains. The Wildhorse Creek floodplain contained more wetlands (40), the largest wetland (148 ha), and a larger mean wetland size (14.1 ha) than did Rush Creek. No permanent natural wetlands are known to exist within the floodplains at the present time.

The original (1871) 12,102 ha of forst along Rush and Wildhorse Creeks experienced a 93% and 84% reduction in area, respectively. Additional acreages of undeterminable size were cleared between 1969 and 1976. Most (81%) of the original forest, plus associated wetlands, was lost between 1871 and 1937. It could not be determined whether these changes occurred prior to or after channelization, but the remaining unchannelized segments are bordered by an average of 5-10% more area of bottomland forest than are the channelized segments. This finding and other data supports the conclusion that channelization per se has been a major factor in eliminating riparian forests along the 2 streams.

An estimated 80% of the orginal forest land has been converted to cropland and tame grass pasture. Current plans to channelize upper and lower reaches of Wildhorse Creek, if implemented in association with persistant private land clearing activities, should eliminate any biologically significant riparian habitats along the 2 streams within a few years.

Flora and Fauna Surveys

A total of 243 plant species and 149 vertebrate species were recorded on the 16 study sites. The mean numbers of species of plants and animals were consistently higher for unchannelized sites than for channelized sites except for large mammals (Table 1). Differences between the 2 channel classes were even more striking in terms of relative abundance. Although different indices of abundance were used for each group of animals and plants, the mean values for unchannelized study sites were 2-3 times greater than for the channelized sites (Table 2). Results obtained from the individual plant and animal surveys are presented separately below.

Plant Communities

The most obvious differences between the plant communities on the 7 forested and 9 non-forest study sites has been the substantial loss of woody species where the original forests have been removed. The 9 channelized sites (1 forested) contained a mean of 29.3 species per site compared to a mean of 52.0 species for the 7 unchannelized sites (6 forested). No significant differences ($P<0.05$) could be detected between the channelized forest site and the 6 unchannelized forest sites.

Differences in species diversity and tree reproduction were determined between forested sites subject to frequent flooding (W1, W8, R3, unchannelized) and forested sites which rarely flood. These differences indicate that reduction of flooding by channelization and/or upstream impoundments has had negative effects on reproduction by a number of riparian tree species, particularly pecan (*Carya illinoensis*) and box elder (*Acer negundo*).

Undisturbed vegetated channel zones dominated by weedy annuals ($\bar{x}$=166 stems/100 m^2), often provided the only appreciable wildlife habitat on cropland, grassland, and pecan grove sites. This habitat was especially important as winter cover for fringillids and movement cover for large mammals. Plant communities were similar in channelized and unchannelized portions where grazing did not occur to the water's edge.

The channelized forest site (W5) ranked first in terms of species richness, species diversity index value, and percent vertical

Table 1. Comparison of mean number of species for vegetation and vertebrate groups by channelized and unchannelized site classes.

Site Class	(No. of Sites)	Plants	Amphibians/ Reptiles	Birds	Small Mammals	Large Mammals	Total Vertebrates
Unchannelized:							
Forest	(4)	57.2	11.5	35.8	4.2	11.5	63.8
Forest Island	(2)	46.0	9.0	22.0	4.0	9.5	42.0
Grass (Native)	(1)	43	10.0	33	9	8	62
Mean, all sites		52.0	10.6	31.4	4.9	10.4	57.3
Channelized:							
Forest	(1)	58	6.0	28	6	11	50
Pecan/ grass	(3)	39.0	8.3	30.7	3.7	11.3	51.3
Grass (bermuda)	(2)	27.0	9.5	24.0	4.0	10.5	45.5
Crop	(3)	11.7	6.0	17.3	3.3	11.0	38.3
Mean, all sites		29.3	7.6	24.4	3.9	11.0	45.5

Table 2. Comparison of mean relative abundance index values for vegetation and vertebrate groups by channelized and unchannelized site classes.

Site Class	(No. of Sites)	Vegetation		Amphibians/ Reptiles	Birds	Small Mammals	Large Mammals
		Species Diversity	Vertical Density				
Unchannelized:							
Forest	(4)	2.81	39.3	40.2	13.3	8.9	3.28
Forest Island	(2)	2.96	45.5	24.0	8.5	8.9	4.75
Grass (native)	(1)	0.43	18.7	18.9	4.3	8.3	1.34
Mean, all sites		2.45	38.2	33.6	10.7	8.8	3.12
Channelized:							
Forest	(1)	3.61	40.5	5.1	6.3	5.0	2.58
Pecan/ grass	(3)	1.76	10.5	16.4	5.0	1.2	1.29
Grass (bermuda)	(2)	0.49	9.0	12.4	4.2	1.3	0.83
Crop	(3)	N.A.	N.A.	13.2	4.6	7.5	1.24
Mean, all sites		1.65	10.2	13.2	4.9	3.7	1.23

[1] Number of individuals/100 m.

[2] Mean number of birds/ha/visit, all seasons.

[3] Percent trapping success, NAS census.

[4] Mean number of encounters per 100 m.

vegetation cover in comparison to all other vegetation classes (Tables 1 & 2). However, the riparian zone density (stems/m^2) of herbaceous vegetation on site W5 was much lower (19.54 stems/m^2) than the mean (36.78 stems/m^2) for the 4 sites in the unchannelized forest class. No measurable channel zone vegetation was present on site W5, whereas 3 of the 4 unchannelized forest sites contained dense channel zone vegetation ($\bar{x}$=206 stems/m^2). Tree reproduction (seedlings) was much lower (1.83 stems/m^2) on site W5 than on the most comparable unchannelized forest site (W8, 7.61 stems/m^2) but was comparable to that on the other forest sites.

All but 1 of the 9 non-forested sites have been channelized, and all represent unnatural plant communities, tame grasses or crops. These sites are typified by a relatively low species richness and dominance by 1 or a few species. Cynodon dactylon was the most important species on all tamegrass pasture (2) and pecan grove (3) study sites. Most of the other important species were forbs, characteristic of moderately-to-heavily grazed pastures in central Oklahoma.

Amphibians and Reptiles

A total of 34 species (49% of the 69 possible) were actually located within the two watersheds. Significantly greater ($P \leq 0.05$, t test) numbers of species were found on the unchannelized sites than on the channelized sites (Table 1). Although the mean number of species on unchannelized sites ($\bar{x}$ = 10.6) was greater than that for channelized sites ($\bar{x}$ = 7.6), no clearcut relationships could be established due to considerable variation between sites and vegetation classes. However, the unchannelized forest sites were generally richest in species ($\bar{x}$ = 11.5, range 7-15) while the channelized cropland and channelized forest sites were most impoverished ($\bar{x}$ = 6.0, range 3-10). All grass and pecan/grass sites were quite similar (range 7-10) in species richness.

The relative abundance index (individuals/100 m of transect, Table 2) appears to provide a useful indicator of site quality. Although results for some sites were biased upwards by concentrations of a few species, the means per sites were consistently higher for unchannelized classes than for channelized classes. The mean for the unchannelized forest sites ($\bar{x}$ = 40.2) was nearly twice as large as for any other class while the channelized forest site ($\bar{x}$ = 5.1) ranked the lowest.

Birds

The relative efficiency of the bird census technique, compared to those required in the other surveys, permitted frequent replication and statistically reliable data analyses. The quality of the data, plus the greater mobility of birds in response to environmental perturbations, resulted in this component providing the most sensitive evaluation of site quality and channelization effects on vertebrates.

Totals of 138 and 114 bird species were identified within the Wildhorse Creek and Rush Creek Watersheds respectively. Of these, 112 species were recognized within 500 m of the study sites while 95 species were actually observed on the 300 m x 50 m survey transects. The mean number of species on unchannelized sites was 31.4 compared to 24.4 for all channelized sites (Table 1). The average density of birds was 1017 birds/ha/visit/site on unchannelized sites versus 4.9 birds/ha/visit/site on channelized sites (Table 2).

The summer data at first indicated that the channelized forest and channelized pecan/grass sites were comparable or superior to the 4 unchannelized forest sites in terms of species richness, diversity and relative abundance. The apparent value of these channelized sites essentially collapsed, however, during the critical migration and wintering periods, while the value of the unchannelized forest sites actually increased significantly ($P \leq 0.05$) during those same periods (Heller 1978).

Coefficients of community similarity (C) revealed that species composition and relative abundance (individuals per species) also varied directly with the intensity of habitat alteration. Mean C values for all seasons revealed that species composition was least affected by channelization where riparian forest vegetation was left reasonably intact. However, stenoecious (riparian forest) species, including 5 parulids, were not found on the channelized forest sites. Ten other forest species, found breeding on all unchannelized forest sites, were not consistently represented on the channelized forest sites. Some aquatic oriented species were favored by channelization, i.e., herons were as abundant, swallows twice as abundant, and killdeer (Charadrius vociferus) and kingfisher (Megaceryle alcyon) were over 4 times as abundant on channelized sites as on unchannelized forest sites.

Generally, as the intensity of habitat alteration increased, site values for bird habitat diminished. Species richness, diversity, and numbers per hectare declined, seasonal use fluctuated more widely for intermediate stages, and the woodland forms were ultimately replaced

by grasslands-savannah oriented species.

Small Mammals

A total of 375 individual small mammals, representing 11 species, was encountered on the 16 study sites. Trapping success was usually quite low ($\bar{x}$ = 5.72), indicative of improverished small mammal populations in the riparian ecosystem. Supplemental trapping efforts from August 1976 to June 1977 indicated almost total collapse of the post-summer small mammal populations. The more sensitive species, e.g. shrews, were conspicuous by their nearly complete absence, while the ubiquitous Peromyscus leucopis was found on all but 1 of the 16 sites.

Twelve species collectively were found on both the channelized and unchannelized sites. However, the mean numbers of species and individuals (Table 3), based on all survey techniques, plus the mean NAS percent trapping success (Table 2), were all higher for the combined unchannelized sites than for the channelized sites. The results for individual sites within channel classes were quite variable, however, and appear to reflect the effects of low population densities and/or microhabitat quality.

A potentially useful site quality indicator was derived, based on calculations of the mean distances between trapped males of the same species, averaged by channel type. Chi square analysis indicated a significant ($P \leq 0.05$) difference for Peromyscus leucopis with a mean spacing of 21.3 m on channelized sites compared to 10.8 m on unchannelized sites, i.e. the latter supported higher densities of that species.

Large Mammals

A total of 3688 observations, representing 18 of 22 possible species (including domestic dog and house cat) were recorded on 215,000 m of transect along the 2 streams. Armadillo (Dasypus novemcinctus) (40% of total observations), raccoon (Procyon lotor) (16%) and beaver (Castor canadensis) (14%) were the most frequently encountered species. These 3 species, plus coyote (Canis latrans) and dog, were the only ubiquitous ones. Mink (Mustela vison), muskrat (Ondatra zibethicus), foxes, jackrabbit and spotted skunk (Mephitis spilogale) appeared to be quite rare (total of 10 encounters). Observations of cottontail (Sylvilagus floridana) (11), striped skunk (Mephitis mephitis) (10), and opossum (Didelphis marsupialis) (17) are believed to be too low and indicate insensitivity of the survey technique for these species.

The number of species averaged slightly higher on channelized sites ($\bar{x}$ = 11.0) than on unchannelized sites ($\bar{x}$ = 10.4). Large mammal observations were 2.5 times more numerous on the 7 unchannelized sites ($\bar{x}$ = 3.12 obs.100/ m) than on the 9 channelized sites ($\bar{x}$ = 1.23 obs./100 m). The differences in mean relative abundance is apparently related in part to the presence of forest cover on 6 of the 7 unchannelized sites. However, the value for the 1 channelized forest site (W5, $\bar{x}$ = 2.58 obs./100 m) is substantially lower than that for the 4 unchannelized forest sites ($\bar{x}$ = 3.28 obs./100 m) or the 2 unchannelized forest island sites ($\bar{x}$ = 4.75 obs./100 m). The frequency encounters for unchannelized native grassland (1.34 obs./100 m) was higher than for all channelized non-forest sites, and 60% higher than the mean (0.83 obs./100 m) for the 2 channelized grassland sites (Table 4).

The frequency of encounter values for the 4 cosmopolitan native species (armadillo, beaver, raccoon and coyote) reflect foraging habits and habitat preferences. Armadillo and raccoon were far more abundant on unchannelized (primarily forested) sites than on recent or old channelized sites. Beaver were most frequently encountered on the recently channelized sites due to an impounded segment. Coyotes were most generally encountered on forest island sites and old channelized open pasture or cropland. Data stratification on the basis of channel type (unchannelized, recent channelization, old channelization) as well as vegetation type demonstrates that channelization has had an overall negative effect upon frequency of encounters with large mammals. Species richness values were of little use in evaluating channelization effects, presumably due to the mobility of large mammals.

Channel Status Comparisons

Since a statistically reliable number of replicate study sites within each vegetation type and channel type was not available, comparable study sites within each class were matched and examined on the basis of vegetation and vertebrate species richness and relative abundance (Table 4). These comparisons indicate that, with few exceptions, the unchannelized types exhibited substantially higher numbers of species and higher relative abundance index values than did the channelized sites. Further, comparison of results for recently channelized and old channelized sites, where these occurred in the cropland and grassland types, indicates that once channelization occurs, the biota can decline over time. The old channelized sites had vertebrate values equal to or lower than those for the recently channelized sites. This was not the case for the 2 comparisons of plant species richness in which the older sites contained more species than did the 2 recent sites. The apparent decline in productivity may be a

Table 3. Results of combined small mammal survey methods by channel status and vegetation class averages.

Vegetation Class	Channelized (No. of sites)	Channelized No. of Species $\bar{x}$	Channelized No. of Indiv. $\bar{x}$	Unchannelized (No. of sites)	Unchannelized No. of Species $\bar{x}$	Unchannelized No. of Indiv. $\bar{x}$
Forest	(1)	6	35	(4)	4.2	34.5
Forest Island	(0)			(2)	4.0	18.5
Recan Grove	(3)	3.7	14.0	(0)		
Grass	(2)	4.0	17.5	(1)	9	26
Crop	(3)	3.3	20.7	(0)		
Combined Classes	(9)	3.9	19.3	(7)	4.9	28.7

Table 4. Comparisons of species richness and relative abundance indices by vegetation type for plants and animal groups on comparable old channelized, recently channelized and unchannelized sites, including unchannelized sites above and below channelized segments.

Vegetation Type:	Cropland		Grassland			Bottomland Forest		
	(alf./wheat)	(alfalfa)	(bermuda)	(bermuda)	(native)			
Channel Status:	old chan.	recent chan.	old chan.	recent chan.	unchan.	old chan.	unchan. (below)[1]	unchan. (above)[1]
Study Site No.:	W2	W7	R4	W6	R5	W5	W1	W8
Vegetation								
no. of plant species	8	5	30	24	43	58	63	72
plant spp. diversity	n.a.	n.a.	0.24	0.74	0.43	3.61	3.64	3.45
herb. density (stems/m^2)	—	—	—	—	—	19.54	4.07	57.61
% vertical density (0-2m)	—	—	0.5	0.5	6.5	16.0	8.5	10.5
Vertebrates: no. of species								
amphib./reptiles	5	12	12	11	12	7	18	11
birds	15	18	22	26	33	28	33	34
small mammals	2	4	3	2	9	5	3	3
large mammals	10	12	8	7	8	10	12	12
Total	32	46	45	46	62	50	76	60
Vertebrates: Rel. Abund. Index								
amphib./reptiles[2]	30.10[b]	5.38	5.88	18.88	26.22	5.10	104.29[b]	17.33
birds[3]	3.62	4.16	3.39	5.09	4.26	6.27	13.09	16.18
small mammals[4]	8.06	8.00	2.00	0.50	8.30	5.00	10.60	16.20
large mammals[5]	1.25	1.82	0.75	0.91	1.34	2.58	5.23	4.48

[1] Site W8 above major channelization; site W1 below major channelization.

[2] Number of individuals/100 m of transect; biased by unusually high numbers of <u>Acris crepitans</u> at sites W2 and W1.

[3] Mean number of birds/hectare/visit/for all 4 seasons combined.

[4] Percent trapping success, North American Standard census technique.

[5] Mean number of encounters with large mammal sign per 100 m of survey.

function of progressively more xeric conditions on the channelized sites.

The bottomland forest comparison (Table 4) shows plant and animal data for 1 channelized site (W5) located between 2 unchannelized sites (W1 & W8). Both unchannelized sites ranked higher than the channelized site except for measures of vegetation density.

Both the upstream site (W8) and the downstream site (W1) flood regularly. The main difference between the 2 is that the latter receives the full force of floodwaters moving through the channelized segments. The effects of scouring, deposition and cutting on site W1 are quite obvious in the field. These same effects may also account for a simpler plant community on site W1. The vertebrate species richness is higher on site W1 due only to more species of amphibians and reptiles. The herps and large mammals are also more abundant on this site, while birds and small mammals are more abundant on the upstream site.

CONCLUSIONS

The efforts to locate an appropriate study area for this investigation revealed that natural riparian habitats within the Oklahoma grasslands have nearly vanished. The subsequent discovery that extensive wetlands and bottomland forests once covered the floodplains of the 2 streams we examined provided a startling contrast to the contemporary conditions.

Channelization and land use changes along the 2 project streams have resulted in or facilitated an extensive loss and degradation of aquatic habitat; complete destruction of natural wetlands; nearly complete elimination (86%) of the bottomland forest; accelerated stream erosion; and reduced vertebrate relative abundance and species richness.

Species richness and relative abundance values for amphibions and reptiles, birds and mammals for study sites channelized prior to 1933 show no evidence of site recovery to existing levels on unchannelized sites with comparable land use. In most instances the values for recently (1968-1971) channelized sites exceeded those for old channelized sites. Values for both types were considerably below those for unchannelized sites.

The only clearcut difference in the plant communities on channelized and unchannelized sites was the loss of woody species due to land clearing operations. However, there were indications that reduced flooding has adversely influenced site productivity and reproduction by riparian tree species.

Information obtained in this study indicates that PL566 upstream flood control impoundments, not channelization, have reduced flood frequency and magnitude on the two streams. Both activities, however, have created a progressively more xeric situation which may be the main factor responsible for the lower relative abundance of vertebrates on the channelized study sites.

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Floral and Attendant Faunal Changes on the Lower Rio Grande Between Fort Quitman and Presidio, Texas[1]

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Abstract.--Written and photographic documentation from explorers and settlers demonstrate that the floodplain was historically dominated by cottonwood-willow (Populus fremontii-Salix gooddingii) and screwbean mesquite (Prosopis pubescens) communities. Past and present land and water use practices have resulted in an almost complete elimination of native tree species and a dominance by the exotic salt cedar (Tamarix chinensis). Avian census data from the area show higher bird population densities and diversites in the select mature cottonwood-willow communities than in mature salt cedar communities.

INTRODUCTION

This paper examines historical records containing vegetation descriptions for the Rio Grande from Presidio to Fort Quitman, Texas, and compares past vegetation with current vegetative conditions. The bird species in existing plant communities are examined, and changes in avifaunal diversities and densities since European settlement are evaluated based on our premise that as plant communities change through time so do the attendant bird species.

The correlation of riparian habitats and high avifaunal densities and diversities has been documented numerous times (Carothers 1977, Hubbard 1977, Anderson et al. 1977b, Stevens et al. 1977, and Wauer 1977). Anderson et al. (1977b) found that avian use of the exotic salt cedar (Tamarix chinensis) on the Colorado River was lower than avian use of native riparian habitats, and this general trend has also been observed on the Rio Grande. More avian habitat specialists were found in cottonwood-willow (Populus fremontii-Salix spp.) and screwbean mesquite (Prosopis pubescens) communities during the winter than any other community type; yet in aerial extent these two communities covered less than 40 ha within a 20,000 ha study area (Engel-Wilson and Ohmart 1978). This is highly important in view of the decreasing area of native riparian habitat and its replacement with agriculture or salt cedar (Robinson 1965, Harris 1966, and Horton 1977).

Historically the trade route along the Rio Grande from Presidio to Fort Quitman, Texas, was traveled infrequently due to the rugged terrain and hostile Indians. The narrow and densely vegetated floodplain paralleled by the rugged upland terrain made travel difficult and frequently impossible, so few travelers visited the area. Consequently early accounts are scarce, but they do describe the nature of the riparian plant communities that occupied this floodplain.

Spaniards were the first Europeans to establish settlements on this section of the Rio Grande. Forts and missions were established at Presidio as early as 1609 (Bancroft 1886) and at El Paso in 1683 (Espinosa 1940). In 1582 an early Spanish explorer, Espejo (Hammond 1929), wrote of the extent of the

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vegetation and the plant communities of the Rio Grande just above San Bernardino (now Presidio, Texas). He stated:

> It is such a river that all of these three leagues [in width] [1 league≃4 km] are covered with numerous groves of poplars and willows there being in it very few willows or any other sort of trees.

In 1846 Whiting (Bieber 1935) wrote of the vegetation he saw along the river during his march to establish a wagon route from San Antonio to El Paso as he followed the Rio Grande from Presidio northward (Fig. 1).

Figure 1. Map of the Rio Grande from El Paso to Presidio, Texas.

He viewed the floodplain from a hill overlooking Presidio and Ojinaga, Chihuahua and wrote:

> Saturday, March 24...We soon came in view of the Rio Grande with its green valley and cottonwood groves. Friday, March 30...Nearly opposite the Mexican town we passed a fine part of the valley where the mesquite, the willow and cottonwood abound in size, and where some judicious and tasteful clearing would make a pleasant site for quarters of a post,... Our trail...between cottonwoods, which almost everwhere line the banks of the river, and the gravel ridges which put out from the hills or rather mountains [Chinati Mountains] on the right.

> Saturday, March 31...On our left on the opposite bank is the North end of the Sierra Grande [Sierra Alto]. On our right [is] a high and large mountain which I have called "Mount Barnard" [Chinati Peak]. The travel has been much interrupted by chaparral, the cactus in every variety, enormous palmitios from fifteen to twenty-five feet high, and every kind of thorn.

> Monday, April 2...On account of the undergrowth and the willow, our progress was laborious and slow, and in many places we were forced to the hills...the Rio Grande with its pale green fringe of cottonwoods and willows, formed a pleasant picture. Towards dusk we reached a bottom where though the grass was poor, we were obliged to camp.

> Thursday, April 5...we saw a beautiful valley with its usual clothing of cottonwood, stretching to the northward...To our right now lies...a rugged and high mountain...this I called "Mount Chase." [Eagle Mountain]. Monday, April 9... continued the march in one unbroken valley, through broad and level bottoms heavily timbered with large cottonwoods...we saw a flock of twenty-five huge white pelicans ...Three large,black-tailed deer, the mountain species were wounded...At four the march was resumed...still in the extensive groves of alamos [Cottonwoods], becoming wider as we advance. In this tract the grass is generally poor...

> Tuesday, April 10...Our trail still lay in the broad cottonwood bottom. The soil, nearly destitute of grass,...Wednesday, April 11...This trail lies through a fine tract, heavily timbered--the trees are very large. We saw nothing of the southern chaparral and undergrowth to impede us... We are now opposite to the island called "La Isla"...[near San Elizario] a mexican visited our camp...told us we were thirty miles from El Paso.

The flora of this section of the Rio Grande Valley was described by Dr. Parry who accompanied the United States and Mexican boundary survey in 1857.

> In the valley of the Rio Grande we frequently find a heavy growth of cotton wood and willows. The "screw bean," Strombocarpa pubescens, often occupies large tracts, accompanied by a dense undergrowth of Baccharis salicina. The low saline places produce an abundance of Obione canescens, while on the higher

ground Tessaria borealis is a common plant. (Emory 1859).

The early descriptions of Espejo and Whiting indicate there was little change in the vegetation along the Rio Grande between 1582 and 1846. Farming and livestock operations were initiated by the Spanish in the late 1500's and reached their zenith in the late 1800's and early 1900's. By the early 1900's much of the bottomland vegetation, mostly cottonwoods, had been removed to develop the riparian floodplain for agricultural purposes (Horton 1977), building material (Emory 1859), livestock forage (Galvin 1966), and fuel.

Photographs of the area in 1918-1919 show a dramatic change in the vegetation of the alluvial floodplain from that described by Whiting in 1849. The only remaining cottonwoods and willows were those along the river and along the margins of the fields (Plate 1).

An assessment of the plant communities in the study area, from March 1977 to March 1978, demonstrated there has been a drastic change in species composition and aerial extent of the native plant communities during the past century. The degree of clearing in the valley was determined by comparing hectares under cultivation in the early 1900's to the present time. The total area under cultivation in 1928-1930 was 7,280 ha (IBWC 1978), and by 1977 this had dropped to 4,700 ha (Engel-Wilson and Ohmart 1977). Peak values for Mexico were 6,228 ha in 1949 (IBWC 1978). The total cleared may be somewhat less than the sum of the two extremes due to boundary shifts. shifts.

The subsequent decline in agriculture appears to be due to several factors and/or a combination there of:

1. Increased use of water upstream
2. Construction of dams upstream (Elephant Butte 1919 and Caballo 1938)
3. Economic depression of the 1930's
4. Floods of 1942 and 1966
5. Increased salt accumulations in floodplain soils which reduced agricultural productivity

Although there are 4,800 ha (23 percent of the floodplain) of recognized agricultural land in the valley, it is noteworthy that there are probably less than 800 ha under production, the remaining being fallow or in pasture.

Due to the decrease in agricultural activity, the floodplain was left open for the invasion of the exotic salt cedar (Harris 1966, and Robinson 1965) (Plate 2). Cottonwoods and willows were unable to grow in their former areas because 1) the abandoned soils were not suitable, 2) the water quality and availability were inadequate, and 3) annual floods had been stopped thereby eliminating soil suitable for seed propagation. The very nature of salt cedar growth along intermittent river courses helps salt cedar disperse into low-lying farmland. Intermittent flows allow seedlings to invade the channel during reduced flows, and when the water is high the seedlings trap the sediment. Annual repetition of this process eventually results in soil and vegetation blocks in the channel, which causes channel shifts and flooding of adjacent areas (Robinson 1965, and Harris 1966).

Plate 1. Candelaria 1918. Looking down river one can see numerous large cottonwoods and much agricultural activity.

Plate 2. Candelaria 1974. Most of the vegetation is salt cedar with little riparian vegetation.

In the study area in 1977 there were 5,600 ha of salt cedar which comprised about 27 percent of the floodplain vegetation (Engel-Wilson and Ohmart 1977). Only about 12 ha of mature cottonwood and willow persisted which made up only 0.06 percent of the floodplain. This did not include isolated individuals along canals and fields. Plates 1 and 2 contrast the abundance of cottonwood in 1918 versus 1974. The remaining floodplain was made up of a mixture of honey mesquite (Prosopis velutina) and other desert shrubs (9600 ha or 46 percent).

Methods

A survey of historical literature and photographs was conducted in the libraries of Arizona State University, University of Texas at El Paso, and El Paso City.

Transects were established in nine mature salt cedar communities comprising a total of 150 ha. One transect of 10 ha was established in a cottonwood-willow association.

These areas were sampled for bird densities each month for one complete year using the Emlen (1971) technique (Anderson, et al. 1977a) Densities were expressed as the number of birds per 40 ha and presented as monthly means for each of five seasonal groups: March-April (MA); May through July (MJJ); August-September (AS); October-November (ON); and December through February (DJF). Species which occurred in fewer than two seasonal groups for both community types were not used in the comparisons. Also ducks, herons and raptors were excluded from the analysis.

Foliage Height Diversity (FHD) and relative foliage volume (RFV) were measured in each community using the board technique (MacArthur and MacArthur 1961).

Percent ground cover was estimated using a 5 m^2 area. Percent ground cover by plant species was estimated to the nearest 5 percent in the 5 m^2 plots. Plots were located 5 m to the right and left of the transect on 61 m spacing beginning at 15 m from the beginning of the transect. The sums of the percentage for each plant species for a transect was divided by the number of 5 m^2's to derive the mean percentage of each plant species for the transect.

RESULTS

Vegetation

Salt cedar forms a dense monotypic stand with 91 percent ground cover and only traces of annuals, forbs and other shrubs. The cottonwood-willow community is a multi-layered association of trees, shrubs and forbs. Percent ground cover for the most common plants are: cottonwood 5 percent, willow 14 percent, salt cedar 7 percent, seepwillow (Baccharis spp.) 17 percent, Johnsongrass (Sorghum halepense) 34 percent and dock (Rumex spp.) 32 percent.

The relative foliage volume (RFV) in the salt cedar community was 2.848 m^2/m^3 with 0.256 m^2/m^3 RFV above 7.5 m with no vegetation above 9 m. The RFV in the cottonwood-willow community was 6.208 m^2/m^3 with 0.499 m^2/m^3 RFV above 7.5 m and having vegetative volume occuring up to 12 m.

Birds

The highest number of species occurred in salt cedar during March-April (see Table 1). The lowest numbers of species (17) were detected in the cottonwood-willow association (Table 1) in these same two months. In part, the latter may be an artifact of the small number of samples from the cottonwood-willow community at the beginning of the study. The number of species recorded in low densities (i.e. < 1/40 ha) in salt cedar was 10 and one in cottonwood-willow in MA. If very low density species are ignored, the number of species seen in salt cedar versus cottonwood-willow during MA is reduced to 16:20. In the remaining seasons, little fluctuation in the number of species in the cottonwood-willow community was observed (27 May through July, 26 August through September, 27 October through November, and 23 December, January, and February).

Densities were low for both communities in MA (475 CW, 330 SC), but increased to a peak in SC in MJJ (486) and to an AS peak (749) in CW. Both communities had decreased densities in ON (76 SC, 569 CW) and densities in SC continued to decline in DJF (67). However avian densities in CW increased to 744/40 ha in DJF due primarily to the influx of granivores and small insectivores.

Differences in the bird populations of these two communities became more striking when a large portion of the dove population was removed from the consideration. Doves gain only a small fraction of their total food intake in the communities in which they nest, consequently we feel a reduction of 90 percent of the doves is ecologically valid. The difference in total birds with this adjustment is dramatic between cottonwood-willow and salt cedar in MA (418 to 181) MJJ (598 to 262) and ON (657 to 80), respectively. Salt cedar appears to be very good nesting habitat for White-winged Doves as they reached nesting densities in the Candelaria area of 28 nests per season

Table 1. Bird densities (#/40 ha) by month group for cottonwood-willow (CW) and salt cedar (SC) communities on the Rio Grande at Fort Quitman.

	MA[1]		MJJ[2]		A-S[3]		O-N[4]		DJF[5]	
	CW I	SC II	CW I	SC II	CW I	SC II	CW I	SC II	CW I	SC II
Gambel Quail (*Lophortyr gambelii*)	23	1	13	5	81	1	35	2	58	0
Mourning Dove (*Zenaida macroura*)	9	17	16	28	27	9	15	0	0	0
White-winged Dove (*Zenaida asiatica*)	53	149	107	221	76	100	0	0	0	0
Roadrunner (*Geococcyx calfgonianus*)	0	1	0	0	0	1	6	0	2	0
Yellow-billed Cuckoo (*Coccyzus americanus*)	0	0	9	1	6	0	0	0	0	0
Black-chinned Hummingbird (*Archilocus alexandri*)	38	33	19	10	3	1	0	0	0	0
Ladder-backed Woodpecker (*Picoides scalaris*)	6	1	2	1	3	2	6	4	11	3
Common Flicker (*Calaptes auratus*)	0	2	0	0	0	0	2	2	0	0
Ash-throated Flycatcher (*Myiarchus cinerascens*)	0	2	3	1	0	2	0	0	2	0
Say Phoebe (*Sayornis saya*)	3	0	0	0	0	0	0	1	7	1
Black Phoebe (*Sayornis nigricans*)	0	0	0	0	11	1	11	1	12	1
Vermilion Flycatcher (*Pyrocephalus rubinus*)	40	1	7	1	7	0	6	0	4	0
Cliff Swallow (*Petrochelidon pyrrhonota*)	0	0	4	0	29	4	0	0	0	0
Verdin (*Auriparus flariceps*)	8	1	0	2	18	4	29	3	20	2
Bell Vireo (*Vireo bellii*)	3	2	13	5	26	2	0	0	0	0
Black-tailed Gnatcatcher (*Polioptila melanura*)	0	1	0	1	0	0	0	0	6	1
Lucy Warbler (*Vermivora luciae*)	0	9	2	5	0	0	0	0	0	0
Yellow-rumped Warbler (*Dendroica coronata*)	130	4	0	0	0	0	10	17	13	8
Orange-crowned Warbler (*Vermivora celata*)	0	0	0	0	0	1	18	1	6	0
Yellowthroat (*Geothlypis trichas*)	0	5	50	17	93	3	6	0	0	0
Yellow-breasted Chat (*Icteria virens*)	0	17	94	55	54	11	0	0	0	0
Summer Tanager (*Piranga rubra*)	0	16	29	29	32	11	1	1	0	0
House Finch (*Carpodacus mexicanus*)	80	10	116	16	50	4	12	1	237	0
Brown Towhee (*Pipilo fuscus*)	0	1	0	0	0	0	41	0	42	0
Green-tailed Towhee (*Pipilo chlorurus*)	0	0	0	0	0	0	17	1	6	0
Cardinal (*Cardinalis cardinalis*)	0	8	1	2	0	2	0	1	31	1
Painted Bunting (*Passerina ciris*)	0	0	38	10	32	2	0	0	0	0

Table 1 (continued)

	MA[1]		MJJ[2]		A-S[3]		O-N[4]		DJF[5]	
	CW	SC	CW	SC	CW	SC	CW	SC	CW	SC
	I	II	I	II	I	II	I	II	I	II
House Wren (Troglodytes aedon)	0	1	0	0	0	0	18	1	5	0
Long-billed Marsh Wren (Cistothorus palustris)	0	0	0	0	0	0	11	0	13	0
Bewick Wren (Thryomanes bewickii)	2	3	1	2	0	3	38	8	22	9
Mockingbird (Mimus polyglottos)	3	4	4	6	6	1	0	0	0	0
Crissal Thrasher (Toxostoma dorsale)	0	1	0	0	6	1	12	2	1	1
Hermit Thrush (Catharus guttatus)	0	0	0	0	0	0	0	2	0	1
Northern Oriole (Icterus galbula)	0	0	2	1	3	0	0	0	0	0
Orchard Oriole (Icterus spurius)	0	1	48	8	28	2	0	0	0	0
Red-winged Blackbird (Agelaius phoeniceus)	1	14	11	5	6	0	0	0	0	0
Great-tailed Grackle (Quiscalus mexicanus)	0	9	11	15	52	0	3	0	0	0
Brown-headed Cowbird (Molothrus ater)	0	7	53	28	2	0	0	0	0	0
Loggerhead Shrike (Lanius ludovicianus)	0	0	0	0	2	1	2	0	0	0
Ruby-crowned Kinglet (Regulus calendula)	12	4	0	0	0	0	41	24	64	32
Blue Grosbeak (Guiraca caerulea)	0	0	29	4	56	2	0	0	0	0
Lesser Goldfinch (Carduelis psaltria)	0	0	25	6	40	7	3	1	0	0
White-crowned Sparrow (Zonotrichia leucophrys)	35	0	1	0	0	0	139	1	108	5
White-throated Sparrow (Zonotrichia albicollis)	0	5	0	1	0	0	0	0	0	0
Chipping Sparrow (Spizella passerina)	29	0	0	0	0	0	58	2	0	2
Song Sparrow (Melospiza melodia)	0	0	0	0	0	0	17	0	31	0
Swamp Sparrow (Melospiza georgiana)	0	0	0	0	0	0	12	0	43	0
Numbered Species	17	30	27	28	26	25	27	20	23	13
Density All Birds #/ 40 ha	475	330	708	486	749	178	569	76	744	67
Denisty 10% Doves	419	181	598	262	657	80	556	76	744	67
Diversity All Birds	2.243	2.248	2.670	2.160	2.840	1.926	2.750	2.267	2.381	1.795
% of Max	0.792	0.660	0.810	0.648	0.872	0.598	0.834	0.757	0.759	0.700
Diversity 10% Doves	2.124	2.879	2.659	2.737	2.790	2.853	2.714	2.267	2.381	1.795
% of Max	0.750	0.846	0.804	0.821	0.855	0.886	0.823	0.757	0.759	0.700

[1] March to April

[2] May, June, and July

[3] August to September

[4] October to November

[5] December, January, and February

per 0.4 ha and population densities of 506 per 40 ha (Engel-Wilson and Ohmart 1978).

Bird species diversities in CW were higher than those in SC when all birds were included. The diversity in SC was higher than that in CW when 10 percent of doves were used in the calculation. Bird species diversities in CW ranged between 87 percent (AS) and 76 percent (DJF) of maximum when all birds were used and slightly lower when 10 percent of the doves were used. In SC BSD percent of maximum increased in MA, MJJ, and AS when 10 percent of doves were used in the calculations 65 to 82 percent MJJ, and 60 to 87 percent AS.

Both communities were compared for each seasonal group using a formula of ecological overlap (Horn 1966). The salt cedar overlap with cottonwood-willow was lowest in MA at 50 percent (see Fig. 1) and highest in MJJ at 85 percent. After the peak in MJJ overlap decreased to 70 percent AS, 65 in ON and to 62 percent DJF.

Conclusion

Historically the study area along the Rio Grande had large and extensive tracts of cottonwoods. Past records also demonstrate that little change occurred until after the mid 1800's, when the area became settled and the alluvial floodplain converted to agriculture. By the turn of the century most of the native riparian vegetation had been cleared. Today there are scattered remnants of the native vegetation, and isolated cottonwoods have been spared along the edge of fields or canal banks to offer shade for domestic livestock or workers during the hot summer months.

Man's activity in the valley brought about the removal of much of the cottonwood-willow community. The few remaining trees continue to flower and fruit, and an occasional seedling can be found. But intensive grazing by domestic livestock quickly eliminates any cottonwood seedling or sucker that appears. Cottonwoods are not the only vegetation which is browsed in the area. Cattle and goats were observed eating yucca (*Yucca* spp.), ocotillo (*Fouquieria splendens*), prickley pear (*Opuntia* spp.), and crown of thorns (*Koberlinia spinosa*).

Overgrazing has been one factor which has prevented reproduction of the cottonwood-willow community in the area. A second factor has been the reduction of flows and the elimination of flooding during the time in which cottonwoods and willow seeds are viable. Cessation of flooding is the result of increased water use and the construction of dams upstream. Also important has been the invasion of the exotic salt cedar. Salt cedar has the ability to colonize areas after summer rains because its flowering and fruiting cycles are such that there is a continual supply of seeds to germinate when the soil is moist (Harris 1966). Once a dense carpet of salt cedar seedlings has developed little light penetrates to the soil for germinating cottonwoods or willows. Should the latter germinate and survive, the future of cottonwoods is bleak, for in a few years the debris laden community burns. Fire encourages the dominance of salt cedar by removing other species which are less fire adaptive (Ohmart, Deason, Burke 1977). Salt accumulations (discussed by Ohmart *et al.* 1977) may also have played an important role in the elimination of cottonwoods as sediments clogged the channel and spread salt-laden waters laterally.

With the loss of the cottonwood-willow community and its replacement by salt cedar, there was a change in the vertebrate populations. Salt cedar has a high total bird population in the breeding season (mostly doves), but during the winter the densities are very low. Cottonwood-willow communities not only contain a higher density of birds than salt cedar but also support a higher species diversity and richness. This same pattern was found in these two communities on the Colorado River (Anderson and Ohmart 1977).

Several species in the study area have a high affinity for the cottonwood-willow association. These are the Brown Creeper (*Certhia familiaris*), Common Flicker (*Colaptes auratus*), Yellow-bellied Sapsucker (*Sphyrapicus varius*). porcupine (*Erethizon dorsatum*), and beaver (*Castor canadensis*). These species occur in very low densities and will probably disappear as cottonwoods are extirpated. Other bird species which will be reduced in density with the demise of the cottonwood-willow community are orioles (Icteridae), Cardinals (*Cardinalis cardinalis*), many species of warblers (Parulidae), Lesser Goldfinches (*Carduelis psaltria*), Long-billed Marsh Wrens (*Cistothorus palustris*), and some sparrows (Fringillidae). Mammalian species associated with the cottonwood-willow community, such as the cottonrat (*Sigmodon hispidus*), house mouse (*Mus musculus*), and harvest mouse (*Reithrodontomys megalotis*) will suffer a similar fate. Such species as the Black Hawk (*Buteogallus anthracinus*), Yellow Warbler (*Dendroica petechia*), and arboreal lizard have already been extirpated in the area.

A 442 km reach of river that was once dominated by cottonwoods and willows has been reduced to a few ha of this community. Unless action is taken to preserve the remnant areas of cottonwoods and willows and plant others;

and protect them from livestock and fire, the remaining trees will eventually die, leaving no successors. Plantings of cottonwoods should be an integral part of any federal or state project conducted in this or any other part of the Rio Grande.

At present only a few of the species that are designated as endangered by the U. S. Fish and Wildlife Service 1977 live in cottonwood-willow communities. But as these habitats continue to be eliminated throughout the Southwest the species that are restricted to these habitats may very well be reduced in number so that they are classified as rare or endangered.

Johnson et al. (1977) stated that riparian habitats were the most productive and possibly the most sensitive habitats in North America. He recommends that they should be managed accordingly. It is our opinion that Johnson's recommendations be followed. One of the first steps would be to initiate efforts to have cottonwood-willow associations and water dependent communities in the Southwestern United States placed on record as being endangered habitats. These areas should have the same protection as that accorded endangered plants or animals.

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Values of Floodplain Wetlands and Other Riparian Ecosystems

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Who Loves a Swamp?[1]

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"A town is saved, not more by the righteous men in it than by the...swamps that surround it."

Henry David Thoreau (1851)

Abstract. Traditional utilitarian and aesthetic rationales in the American conservation movement could not justify the protection of the wetlands, but the science of ecology led to public recognition of the value of "ordinary" environments such as wetlands and rivers. There are, however, ironic implications of this new-found interest since the environments in question are especially susceptible of being loved and managed to death.

THE THREE CONSERVATION RATIONALES

A utilitarian rationale launched the American conservation movement. People valued the environment for what it could do for people. Trees were potential timber, waterfalls hydropower sites and animals meat in the pot. It was a simple matter of economics. Utilitarian conservation inspired George Perkins Marsh in the 1860's, led Gifford Pinchot to advocate the wise use of the "forest reserves" (later "national forests") in the 1890's and still underlies a large portion of concern for the environment.

Aesthetic considerations lay behind the second oldest tradition in American conservation history. If utilitarianism focused on man's stomach, aesthetic conservation stressed his spirit. Nature could be beautiful as well as useful. Because appreciation of beauty did not entail consumption, aesthetic conservation meant preservation. It gave rise to one of the United States' most admirable contributions to world civilization: the national park idea.

Until well into the 20th century, aesthetic conservationists confined their concern to the preservation of spectacular environments. Yellowstone, Yosemite and the Grand Canyon had in common the fact of being unusual if not unique. In the hallowed American tradition, the biggest was invariably the best. If a natural feature was not the largest, highest or deepest, it received short shrift according to the philosophy of what might be termed monumentalism. Only "crown jewels" received protection. There was a fear of degrading early preservation efforts with the less-than-spectacular. So Niagara Falls, Mount Rainier, Crater Lake and the redwoods became the favored causes of the nature protection movement. Significantly, the first "national monument" established by Presidential proclamation under the 1906 Antiquities Act was Wyoming's Devil's Tower -- the largest volcanic monolith of its kind. Why worry, early aesthetic conservationists wondered, about the unextraordinary in nature? Swamps and river shorelines deserved no special treatment.

The rise of the science of ecology after 1920 created an intellectual foundation for the third and most recent rationale for conservation in the United States. As opposed to the utilitarian and aesthetic traditions, the ecological basis for nature protection saw value in what was formerly regarded as useless and ordinary. More precisely, ecology broadened the concepts of utility and beauty to include everything that contributed to the intricate, interdependent community of life forms and earth forms. Ecosystems (the word was not coined until 1935) were gradually perceived to be as worthy of protection and professional management as

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thousand-foot waterfalls and giant geysers. Ecological processes, not just monumental individual objects, received attention. This shed a completely new light on the ordinary in nature. Swamps, for example, benefitted from the new perspective. The teeming, dynamically-balanced world of an acre of wetland became in its own way as awesome as El Capitan and Old Faithful.

It followed from the ecological rationale for conservation that even swamps could be the objects of the nature protection movement. Signaling the new attitude was the 1934 designation of Everglades National Park in Florida. The protection of the vast wetland marked a revolt against monumentalism. Everglades had no waterfalls, geysers, canyons or snowcapped peaks. Its highest elevation was only eight feet above sea level! Opponents demeaned Everglades on the floor of Congress as a "snake swamp park" and succeeded in blocking financial appropriations for its management for five years. Defenders of this new kind of park replied that what was being preserved here was an extraordinary ecosystem. In other words, what was extraordinary was the ecosystem. The huge swamp, they argued was every bit as wild and beautiful, and as valuable for science and for recreation, as, say, the Grand Canyon or the Grand Tetons. The gradual spread and refinement of this understanding among Americans led to legislation like the National Estuary Protection Act (1968) and the National Wild and Scenic Rivers System (established 1968) and to the present symposium.

TEN VALUES

In thinking about the values of wild wetland ecosystems, it may be helpful to attempt a distillation of the best thinking past and present on the value of non-monumental wild places in general. What, after all, is the point of worrying about the future of swamps and shorelines? Ten answers might be suggested.

1. Normal Ecological Processes

With so much of the environment disturbed by technological man, wild places such as wetlands take on importance as models of ecological balance and land health. They constitute a criterion against which to measure the impact of civilization. Without wildness, we have no conception of really natural conditions. Ecology needs wild places as medical science needs healthy people.

A corollary to this value of the wild stresses its importance to the preservation of biological diversity and complexity. In wilderness the plants and animals that man currently regards as "useless" find sanctuary. Life forms are banked against a time when they may be vitally important to man and the ecosystem. The gene pool is maximized. As David Brower is fond of saying, wilderness holds the answers to questions man does not yet know how to ask. Aldo Leopold pointed out with reference to diversity (especially the preservation of rare and endangered species) that the first axiom of successful tinkering is to save all the parts.

Basic to this argument is the realization that the life force on this planet has much more to do with wildness than with the controlled order man began to impose 15,000 years ago with the advent of hearding and agriculture. End wildness and you end, at least in part, the evolutionary processes responsible for all life, man's included. We have, to be sure, made impressive strides in understanding and controlling the environment. Not everything we have touched has turned to ashes. Our impact on the earth has often been beneficient. But in the course of modifying the natural order man inevitably picks and chooses, favors and puts down. The criteria used in this selection are not the natural ones developed over a billion years. A new force is driving evolution, and the responsibilities attendant with playing God are awesome. The uncertainties involved should weigh heavily on the conscience of the precocious ape called man. We should not casually trade off billion-year old processes for the technological cleverness of a few hundred years. It is particularly disturbing to end ecological options. Wildness keeps them open. It is a hedge against man's potential to make mistakes.

With reference to wet wildlands in particular, the argument is now commonplace that these environments are the earth's most biologically productive. Their importance in food chains and, ultimately, in the energy systems that sustain life is beginning to be scientifically documented and publicly accepted. If nature bats last, wetlands may be the natural team's designated hitter.

2. Crucible of the American Character

In 1936 Gertrude Stein noted that, "In America there are more places where nobody is than where anybody is. That is what makes America what it is." This recognition that space--emptiness, solitude, wilderness, vast unmodified distances--is the distinguishing element in the American experience is widely shared. Frederick Jackson Turner's insight about the significance of the frontier was essentially the same as Stein's. And Wallace Stegner noted in 1960 that, "something will have gone out of us as a people if we ever let the remaining wilderness be destroyed...if we drive the few remaining members of the wild species into zoos or to extinction."

The environment of origin is clearly important in defining and sustaining national character. Leo Marx has shown the importance of the middle (rural) landscape, the garden, in the American experience. But is this condition a midpoint on the spectrum of environmental options running from the totally wild to the totally civilized? Is it reached by blending life styles and life settings? The alternate way to emphasize the middle is to alternate the extremes. An Iowa farm, it could be argued (and has by Paul Shepard), represents the worst, not the best, of both worlds. Perhaps the optimum situation for Americans, the one truest to their origins and character, is not permanent residence at Walden Pond but a season at Harvard and a season in the Maine woods. The alternation of San Francisco and the Sierra, Boston and the Adirondacks, may make more sense in this respect than a perpetual Middletown. The American character, after all, was the result of quite civilized people coming into contact with wildness. As Wallace Stegner puts it, "an American, insofar as he is new and different at all, is a civilized man who has renewed himself in the wild." The frontier, then, might be seen not as a compromised rural condition but as a boundary between wildness and civilization. Preservation of these extremes, not the middle landscape, might be the best assurance of keeping alive the traditional American character.

3. Creativity

Thinking about the need for self-reliance in the creation of a uniquely American art and letters, Ralph Waldo Emerson urged his expansion-minded countrymen to "also inhabit the western lands of the mind." Henry David Thoreau also discerned a correspondence between the unexplored West and "our own interior white on the chart." Over a century later, when the amount of wild "white" space in the Lower 48 had shrunk to about 3% of their area, poet Gary Snyder lamented that "there is not much wilderness left to destroy and the nature in the mind is being logged and burned off." Common to these perceptions is the connection between wildness and creativity.

It is common knowledge that beautiful, frequently wild environments inspire great art, poetry and literature. Unmodified nature is, in fact, often its subject. Certainly in the American cultural experience, as Neil Harris and J. Gray Sweeney have pointed out, the advent of a distinctive and distinguished style and subject awaited the coming to grips of Americans' minds with what was different about their homeland--namely its wildness. Certainly artists like Thomas Cole, Frederick Church and Thomas Moran followed this formula, and William Henry Jackson and Ansel Adams continued it in the new medium of landscape depiction: photography. Many date the start of American literature with the publication of James Fennimore Cooper's The Pioneers in 1823. The wild context made the novel different, and wildness continued to inspire writers as diverse as Willa Cather, William Faulkner, Robinson Jeffers and Gary Snyder. The music of Ferde Grofé and John Denver should not be overlooked as a cultural product of wilderness experience.

But can we go further than this to posit a link between the creative process and wildness? Thoreau offers a starting point with his idea that wildness acts as intellectual fertilizer. Blended in the correct proportion with the refining "sand" of civilization, creativity flourished. Thoreau and Cole, among many other 19th century thinkers, were preoccupied with the idea that the founders of Rome were suckled by a she-wolf. Greatness followed. But when Rome's wild woods became buried under too many warm baths, its culture and finally its social and political structure collapsed. The conquerers, significantly, were wilder people from the forests and steppes to the north and east.

For Thoreau, the Transcendentalist, wild nature reflected beauty and moral truth more dramatically than did those parts of the earth on which man had laid a veneer of civilization. In 1851 he referred to wildness as "the raw material of life." Edward Abbey thought similarly a century later when he wrote that in wilderness we "confront, immediately and directly...the bare bones of existence, the elemental and fundamental." Now if great art depends on successive penetrations to and interpretations of this base stratum of reality, then wildness is indeed a cultural source and font of creativity. It makes possible that "original relation to the universe" that Ralph Waldo Emerson believed to be the basis of any creative effort. The alternative is a cultural product based on a prior cultural product, synthesis based on synthesis. Originality ends. So does one of the most important goads to discovery: the unknown. This might be one of the ideas at the root of Thoreau's dictum that "In Wildness is the preservation of the World." Aldo Leopold may have had something similar in mind when he concluded a discussion of the value of "raw wilderness" by noting that "it is only the scholar who appreciates that all history consists of successive excursions from a single starting-point, to which man returns again and again to organize yet another search for a durable scale of values." Discovery implies the existence of the unknown. We need, in sum, to know if pathfinding and trailblazing, concepts that originated in the wilderness, have intellectual dimensions and are possible at all in a completely known and controlled world.

Finally, is it worth considering the idea that wildness is itself an artistic form? Replying in the 1930's to the question, "How

many wilderness areas do we need?", Robert Marshall replied, "How many Brahams symphonies do we need?" If wildness *per se* is an intricate form of beauty then its destruction assumes a significance comparable to burning the Mona Lisa or bulldozing Chartres.

4. Historical Document

Historians are beginning to realize that understanding the past involves knowing more than what people said and wrote. The landscape is also a document. It can reveal, more dramatically than conventional records, how people *felt*. Wilderness, wild animals, trails, portages, wetlands, big timber, vast distances and the pioneering way of life are important components of American history and, back far enough, of the human experience. We will not learn much about them in Frontierlands, Zane Grey novels and John Wayne westerns. Nor will we be able to transmit the hope and excitement inherent in the American dream without personal contact with the wild environment that generated it in the first place. Wallace Stegner, for one, sees the remainder of our wilderness as a kind of "bank," a reserve where we keep what is necessary to teach new Americans the essence of their nation's history.

One way to look at this idea is to consider the environment a palimpsest. Like a canvas that has been painted upon time and again, the landscape is a pile of layers arranged chronologically. But only the most recent is visible, typically, in civilized places. In a child's eyes the shopping center or hamburger stand has "always" been there. Wild places, like chips and cracks in the upper coats of a palimpsest, reveal the old patterns. We preserve them, it could be argued, as reminders of the past, as evidence of the environmental foundations on which civilization rests.

We could, of course, just forego the link to the past that wildness provides and be content with written and visual recreations of a reality fast fading into fantasy. But we would be poorer for this social amnesia. We are what we have been. History and its keeping are much more than academic exercises. They are an important part of what being human is all about.

5. Danger and Challenge

One of civilization's supreme ironies concerns the elimination of the challenges, including the fear and pain, that merely surviving in the precivilized world entailed for humans. For eons we dreamed of and labored toward escaping from the anxieties and hardships of a wilderness condition only to find, when we reached the promised land of supermarkets and air conditioners, that we had forfeited something of great value.

The importance of danger stems from its role in human evolution. Time and again it motivated humans to do great deeds, make breakthroughs, discover. Long before success and status entered the picture, fear and pain were energizing forces. They turned the wheels of evolution. As J.R.L. Anderson argues in *The Ulysses Factor*, wildness gave rise to the exploring instinct in a few individuals and their achievements have been of survival value to the race.

Now we are on the brink of the promised land. Civilization gives most people life without fear. To be sure, modern man still dies, and there are new fears associated with taxes and bad breath. But can you think of the last time you were lost? Or attacked by a wild animal? Or forced to cope with hunger and thirst--the real things, not just the pale imitations that follow three sets of tennis? Perhaps contrived challenges such as climbing the outside walls of skyscrapers or marathon running or swimming can satisfy the thirst of some people for physical risk. Perhaps a world can be engineered that outmodes the old risks so completely that the ability to cope with them becomes irrelevant. But if in these regards there is no substitute for the wild, we had best recognize the fact before it is too late.

The value of wilderness under consideration here stems from its ability to strip away the civilization that normally intervenes between man and elemental challenges. In wild places, surrounded by uncontrolled things, humans learn to live with danger again, to be cautious, prudent, inventive. Some people need the uncontrived challenges that only wildness can provide. "It must be a poor life," Aldo Leopold remarked after a lightening strike nearly missed him on a New Mexican ridgetop, "that achieves freedom from fear." From this point of view, "too much safety seems to yield only danger in the long run." Edward Abbey also speaks for those who like the "taste of danger" in their lives and go to the harshest, toughest country. Outward Bound and similar organizations have discovered a thirst in civilized societies for contact with the challeges of wild country even if this means exposure to danger, stress and risk.

6. Freedom, Individual Dignity and Human Diversity

Wallace Stegner has a beautiful way of expressing the relationship between wildness and freedom. He calls wilderness and the idea of wilderness "part of the geography of hope." Americans should understand this better than most societies. The Puritans, searching for religious freedom, found sanctuary and a chance to build anew in a wild New World. When Roger Williams dissented from the Puritans in 1636

he too struck out for the wilderness of Narragansett Bay. The Mormons went to Utah for the same reasons in the 1840's, and the counterculture of the 1960's sought fresh land for fresh beginnings. For these diverse groups wilderness meant the freedom to be different, to change and to reform.

It is widely recognized that wild places and wild things contribute to ecological diversity (see #1 above); the role of wildness in advancing social and intellectual diversity is just becoming apparent. We understand the incompatibility of wildness with totalitarian systems where everything is controlled and there is no place to hide. It is significant that the guerrilla bands opposing such regimes take to the hills or to the swamps. Further study must be made of the proposition that there is a link between external wildness and the capacity of the humand mind for unfettered thought. We are only beginning to understand the brain in terms of a tension between an ordering and a free-wheeling, intuitive impulse. According to some psychologists these ways of responding to reality are centered in the left and right parts of the brain. Civilization (the ordering urge) and wildness (the uncontrolled) may correspond to and support this division.

Wildness, by definition, is the uncontrolled, the unorganized. As such it is fertile ground for deviancy, idiosyncracy, and eccentricity, and we must remember that these words have positive as well as negative connotations. Raymond Dasmann calls wilderness areas "reservoirs of freedom." Joseph Wood Krutch speaks of the wild as "one of the permanent homes of the human spirit." Wallace Stegner links the American Dream, wilderness and human liberty. Without wildness, he argues, "we are committed wholly, without chance for even momentary reflection and rest, to a headlong drive into our technological termite-life, the Brave New World of a completely man-controlled environment." But Aldo Leopold may have said it best. "I am glad," he wrote in 1945, "I shall never be young without wild country to be young in. Of what avail are forty freedoms without a blank spot on the map?"

7. Religion

An important value of the wild for some persons is as a setting for religious activity. In wilderness, as in a church, they attempt to bring meaning and tranquility to their lives. They seek solutions for, or at least ways of coping with, the weightiest problems of human existence. A wilderness experience, for them, is a time to see and share the unity of all things. For example Colin Fletcher says that in wilderness "you regain a sense of harmony with everything you move through...you are part of the great web of life...you know the wholeness of the universe, the great unity." John Muir had the same reaction; for him a wilderness trip was an act of worship. Non-Christian faiths (the American Indians' come to mind) have, of course, long found in wild places a setting for contemplating the oneness of the universe.

For a Muir or a Fletcher, a wild place is just as much a church as a building with a steeple. It follows that the destruction of wilderness could be looked upon as a violation of religious freedom. Few have tried to defend wild places on these grounds. But the American Constitution and fundamental law of many societies protect people in their right to worship as they choose. Does not this ethical norm protect the minority who regard wilderness as holy? Pragmatically, this approach to preservation might be extremely effective.

There are also intriguing practical consequences to the beliefs of Deists and some Romantics that (to paraphrase John Ray's 1691 title) the wisdom of God is manifested in the works of Creation. If nature is religious evidence, and wild nature is the purest evidence of all, then preserving wilderness has a meaning comparable to protecting the Bible and other sacred texts. Even if only a few people felt this way, would not their beliefs warrent respect under political systems that protect minorities?

8. Mental Health

There are several ways of thinking about wildness as a bulwark of emotional and psychological stability. Sigurd Olson emphasizes the ancient, pre-civilized "emotional needs" that modern man can ignore only at the peril of his sanity. What Olson has in mind are the deep, prehistoric satisfactions associated with building a fire, finding a shelter, paddling a canoe, walking a trail. Such wilderness activities put humans back in touch with their biological roots and provide a chance for self-sufficiency that civilization has destroyed. Even René Dubos, the enthusiastic garden earther, writes of the "persistence in man of biological and emotional hungers that developed during his evolutionary past, and that he cannot outgrow." Implied in this idea is the realization that we have been creatures of the wilderness much, much longer than we have been creatures of civilization. In terms of the history of the species, apartments, cars, money and the idea of time (at least as broken into seconds, minutes and hours) are very new and very disconcerting in ways we are just starting to understand.

Our recognition of this idea most often takes the form of a vague need to "get away from it all." Sigmund Freud saw this urge as the result of contact with a civilized order that bred "discontents" in the form of

repressions and frustrations. The point is that civilized existence is too complex and too demanding for most people to assimilate as a steady diet. They need occasional escape, a psychological holiday. Wilderness offers the obvious antidote to too much civilization. People seek the wilds as Thoreau did at Walden Pond to simplify their existence and they return mentally refreshed and prepared, once more, to cope. In this sense wilderness is an alternative to mental institutions and sedatives.

Recently pscyhologists have pondered the relationship between geographical space and psychic space. There are studies that suggest the crowded conditions of the inner city are partly responsible for the social violence characteristic of those places. Americans in particular appear to have a psychological need for space. They sing "don't fence me in" and relate space to personal identity. John Denver sings, "I'm looking for space to find out who I am." It is no accident that the drug culture, seeking in its own way psychological relief from the pressures of civilization, uses terms like "spaced" and "spacy." "Far out" may not be just a casual expression, at least not for those who covet the relief of large, uncontrolled places.

Recently a number of psychologists and psychotherapists have organized as the Wilderness Psychology Group. Their concern is the relationship between wilderness and mental health. Their hypothesis is that contact with wild places promotes self-understanding, self-sufficiency and self-confidence. They point to instances in which mentally disturbed people have benefitted from exposure to wilderness. In 1972, for example, Everest climber Lute Jerstad took 49 mental patients on a 16-day trip. The idea was to "shake them out of their protective habits of defeat, helplessness and passive compliance." At the end of the trip fourteen of the "hopeless" cases, people with whom all conventional therapy had failed, returned to normal life. Most of the others showed significant improvement. The point is that the role of the wild in psychotherapy needs investigation before we eliminate it as a significant factor in the earth environment. Speaking against a proposal that would destroy a major wilderness in the West, J.V.K. Wagar wrote: "We know what man's needs for food and fiber are, but we have not fixed his need for space. We should determine it before this expanse of spaciousness has been shattered."

9. Education for Environmental Responsibility

One often hears the objection that there are more serious environmental problems than saving wildness. The long-term welfare of man and the ecosystem, it is said, depends on solving the "real" environmental problems like pollution, energy, food supply and population. A concern with endangered species and wilderness, the argument runs, is merely cosmetic, like picking up litter. Worrying about the wild is comparable to fussing with the arrangment of the deck chairs on the _Titanic_.

The rebuttal might start with the same metaphor. Wildness, as an educational asset, is essential to stopping the _Titanic_ or altering its course. The most serious environmental problem, the basic one, is _mind_ pollution. Values, attitudes and priorities are at the core of the environmental crisis. They power the whole exploitative juggernaut. Ideas, not merely instrumental machines, are the keystones that must be moved. Humility is part of what is needed, and it stems from a recognition of man's ultimate dependency on nature. Wilderness can drive home the point. Aldo Leopold put it this way: "civilization has so cluttered the elemental man-earth relation with gadgets and middlemen that awareness of it is growing dim. We fancy that industry supports us, forgetting what supports industry." Contact with wilderness is a corrective. It puts man back in scale; exposes his vulnerability.

Wilderness can also teach that community is a concept that does not end with man or what he controls. In wild country we appreciate other orders and other interests because we find our own limited. We see ourselves as members, not masters, of the life community. From this recognition emerges the idea of an expanded ethic, an environmental ethic, which may be the primary intellectual ingredient of a new and harmonious relationship with the earth. Wildness is available to show the way out of the morass of egocentricity that threatens the entire ecological structure.

An appreciation of the meaning and importance of restraint is the final contribution wildness might make to the quest for environmental responsibility. When we establish and preserve the wild, we say, in effect, thus far and no farther toward development. We establish a limit. We accept the concept of self-imposed limitation when it comes to dealing with the environment. For Americans, especially, self-limitation does not come easily. Wilderness reserves are symbols of a revolutionary new attitude. They mean that if we cannot prosper without a dam or mine or mill within the wilderness, then we will limit our prosperity to that extent. We put other considerations before growth. We discover the limits of the earth. Such a discovery, and the consequent need for restraint, is fundamental to the goals of environmental education. Wilderness may be the best evidence we have, in the last analysis, that the earth is not man's oyster.

It may be that we can teach environmental

responsibility with books and film strips and field trips to the backyard brook. But can we give up the assistance of swamps and other wild places, both as symbols and realities, in increasing the impact of the message?

10. Because It Is There

The previous nine reasons, even the first, are arguable in terms of human interest. The final one is not. It simply states that the wild world is good <u>for itself</u>, good, that is, just because it exists.

This perspective has echoes in the "process philosophy" of Alfred North Whitehead. Everything in the world is a necessary part of the changing pattern of relationships that we know as existence. Every event or process has meaning in the total scheme of things or, as Whitehead puts it, "its signification in the universe."

It may be possible to draw from this philosophy the idea that the non-human world has a right to exist just because it exists. The wild is the last repository on earth of the unmodified creative force that explains all things, man included. Leave aside the idea of value, with its inevitable anthropocentric imlications. Wildness is an ultimate reality, existing apart from man's needs and interests. Before civilization is was the total reality. It would resume that role should man falter. The universe, presumably, does not need man; man needs it. And the universe <u>is</u> wildness, the classically uncontrolled. For this reason alone some would say that swamps deserve our respect, maybe our love, and certainly our awe.

LOVING AND MANAGING RIVERS TO DEATH

Rivers in particular have been a beneficiary of the recent surge of American interest in wild places. While most wetlands pose transportation problems that deter recreational visitation, riparian environments are comparatively easily reached. Without mechanized assistance how else can you move through twenty-five miles of roadless country a day without taking a step? Let gravity do the work. Go with the flow. Families that would pale at the thought of a 100-mile backpack eagerly join river trips of the same length. Improvements in equipment (notably the inflatable raft) and river-running technique have transformed a high-risk expeditionary activity into a family vacation. Even heavy whitewater is run for fun, albeit usually with the aid of a professional boatman. Unquestionably rivers have exerted a democratic influence on outdoor recreation, broadening the clientele of wilderness users. A glance at user statistics on the nation's best-documented river proves the point:

Table 1.--Travel on the Colorado River through the Grand Canyon, Arizona

Year	Number of People	Year	Number of People
1867	1?	1960	205
1869-1940	44	1961	255
1941	4	1962	372
1942	8	1963-1964	44
1943-1946	0	1965	547
1947	4	1966	1,067
1948	6	1967	2,099
1949	12	1968	3,609
1950	7	1969	6,019
1951	29	1970	9,935
1952	19	1971	10,385
1953	31	1972	16,432
1954	21	1973	15,219
1955	70	1974	14,253
1956	55	1975	14,305
1957	135	1976	13,912
1958	80	1977	11,830
1959	120	Estimated 1978	15,000

Faced with this surge in popularity and the possibility that fragile riparian environments could be loved to death, managers turned to the idea of carrying capacity. The physical and biological aspects of carrying capacity are relatively easily understood, the erosion of the quality of the resource relatively easily measured. It is more difficult to calculate the psychological carrying capapcity of an environment--the impact of people on people. As an aid to understanding the concept of psychological carrying capacity and its relation to space, consider the following satisfaction curves for three kinds of activity.

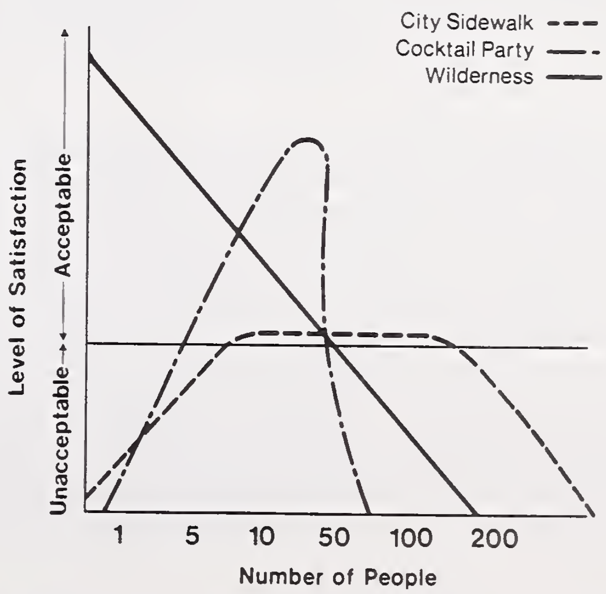

Figure 1.--The Psychological Carrying Capacity Concept

The city sidewalk is an unsatisfactory place (in this case, frightening) with only a few people in sight. A pedestrian could be mugged or raped. The presence of more people raises

the curve over the cut-off point and it remains there until the crowd builds to the point where walking becomes difficult. The cocktail party is similarly unsatisfactory with only a few people rattling around a large living room without much to say to each other. As more guests arrive the party gets going, but the curve turns down as a sardine-like situation develops. Wilderness recreation, on the other hand, is an activity that by definition is more satisfying at lower densities. Large numbers cannot enjoy solitude together. The graph suggest that the wilderness visitor can tolerate other visitors up to a point. Then the wilderness is no longer wilderness; the psychological carrying capacity has been exceeded, the gross-out point reached.

Recreational management, a whole new profession, has arisen in response to these kinds of problems. So have a host of management techniques such as the backcountry permit, campsite assignment, daily and seasonal visitor quotas, no-fire (stove only) rules, and mandatory carry-out of human feces. Only recently are a few iconoclasts beginning to understand that in regard to wilderness, management may be part of the problem as well as part of the solution. The paradox lies in the fact that what attracts many people to swamps, rivers, and wilderness in the first place is that they are environments <u>not</u> controlled by civilized man. Ecological processes proceed unimpaired and, for a time, the visitor can be a part of them. What Robert Marshall called "the freedom of the wilderness" is a vital element in its appeal. Management compromises that freedom, it controls the classically uncontrolled. Wilderness management may, in fact, be a contradiction in terms. If you do succeed in managing a wilderness, you no longer have a wilderness to manage.

The point is this: the managers of wetlands and other wildernesses are not bad guys and girls. Their work is necessary or we would quickly spoil what wildness remains by the sheer number of users. But there are other ways to kill wilderness than by loving it to death. It can be managed to death too. The challenge is to manage so that little management is necessary. In this case, less is indeed more. Upon this seemingly simple yet enormously difficult principle hangs the fate of much that the nature protection movement has tried to achieve. The sad alternative is to have wilderness that is not wild.

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Values of Riparian Habitats to Natural Ecosystems[1]

Laurence R. Jahn[2]

Abstract.--Vegetation in riparian habitats stabilizes soils and supplies organic matter that sustains aquatic communities. Nutrient-rich silt deposited periodically in these habitats by floodwaters enriches soils that support bottomland hardwood forests, forage for wildlife and livestock, and outdoor recreation. Broader applications of management guidelines are required to adjust human-related activities in riparian zones.

It is a pleasure to appear at this symposium and focus attention on the ecological values of riparian habitats to natural ecosystems. This is a dimension that too often has been slighted or overlooked. My objective is to provide some insight to help overcome these shortcomings.

The term "ecosystem" refers to a community of plants and animals, together with its inseparable environment of soils, waters and other elements on which the organisms depend for survival. It is a critical frame of reference for understanding land and water patterns of the landscape, their interrelationships and the need for perpetuating natural functional systems with minimal maintenance or public expense. By better understanding the ecological principles governing terrestrial and aquatic units of the landscape, planning and management of each watershed and individual riparian zone or habitat can be improved on a sound scientific basis.

For practical purposes, a watershed subdivides into three units: (1) freshwater habitats, (2) saltwater habitats and (3) terrestrial habitats. You are very familiar with subdivisions of the latter, which include deserts, grasslands, forests, croplands, rangeland and urban areas. Many of these habitat types can be subdivided further on the basis of dominant vegetation, such as a cornfield or an oak woodlot.

Aquatic habitats or wetlands likewise are subdivided on the basis of topographic characteristics, water chemistry, depth and movement, and existing or potential patterns of aquatic vegetation. Among the 20 or so different wetland types recognized in the United States are several kinds of potholes, marshes, swamps, streams, lakes and man-made impoundments. It is these separate aquatic and terrestrial units that, in various combinations, yield the variety of landscapes we see. It is the differences in characteristics and interlocking relationships among aquatic and terrestrial ecosystems that provide the stability and productivity of both ecological and economic systems.

Watersheds are the fundamental units for understanding these interlocking relationships. Within each watershed, the natural drainage network is dominated by small headwater streams. The quantity and quality of water and physical features of each stream depend on characteristics of the land area, or watershed, drained by that stream. Type of vegetative cover, soils exposed to erosion and sediment release, and land-use activities influence the quantity and quality of surface water and groundwater inflows, and influx of organic matter--such as leaves. These and other factors influence biological activity in each stream.

Surface water drainages unite in a network, and range from small headwater types to midsize streams and finally to such large rivers as the Mississippi. Small streams are processors of natural organic matter that is derived largely from other parts of the watershed--including the riparian zone (Cummins and Spengler 1978). In contrast, the wide, shallow, warm, well-lighted,

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midsize streams contain green plants that produce much of the organic matter. Photosynthetic production is supplemented by inputs from extensive, upstream, headwater networks. Poor light penetration limits plant photosynthesis in deep, turbid waters of larger rivers. They depend primarily on inputs of organic matter from the massive network of tributaries throughout the interlocking system of ever-larger watersheds.

Few people understand that the influence of riparian vegetation is maximal in small streams. Vegetation bordering the channel provides shade that limits plant growth, especially algae, and contributes major quantities of organic matter, such as leaves and twigs. This plant material makes up the bulk of the detritus (dead organic matter and associated microorganisms) that provides up to 90 percent of the organic matter necessary to support headwater stream communities (Cummins and Spengler 1978). The remainder of the organic matter is produced by plants within streams. Channel and floodplain obstructions--such as branches, logs and rocks--enhance retension and concentration of organic matter, thereby facilitating its use locally rather than downstream.

In coastal situations, riparian vegetation provides similar production and protection services, as along small streams. For example, stands of mangroves, with their network of roots, reduce the impacts of high tides and storm surges. Mangrove leaves, as well as plant materials from salt marsh vegetation fringing open waters, provide organic matter that serves as the nutrient base for coastal aquatic communities.

The critical importance of riparian plants in holding soils and supplying and retaining organic matter to maintain productivity of aquatic communities on a sustained basis must be reflected more clearly in water and land management authorities, policies, programs and practices. The first step in this recognition was taken when President Carter issued Executive Orders on Floodplain Management (No. 11988) and Wetland Protection (No. 11990) on 24 May 1977. In February 1978, the U.S. Water Resources Council issued guidelines for all federal agencies to implement those Presidential Executive Orders. Agencies continue to move forward to identify a comprehensive approach to floodplain management that will (1) protect lives and property, and (2) restore and preserve natural and beneficial floodplain values.

This is an important national policy thrust that includes riverine and coastal riparian zones. These are zones where flooding not only is most frequent and damaging, but where natural and beneficial values of land and water are at their maximum. As a variety of resource managers know, riparian zones are well-defined, unique and highly productive habitats. As other speakers will emphasize, wildlife use of these areas, with their available water and maximum edge, is considerably higher per unit than in most other vegetative types.

Water as well as the woody vegetation makes the riparian zone attractive for other uses. Silt, laid down by flood waters, improves sites for growing timber, particularly bottomland hardwood forests. Similarly, the rich soils also provide enriched forage, especially in open areas, for domestic livestock as well as wildlife. Generally flat topography favors less expensive road construction. Quality waters support preferred fish populations. All of these factors, coupled with favorable aesthetic appeal, attract concentrations of recreationists. This variety of demands for uses of riparian zones stimulates conflicts and mandates site-specific planning and management to assure that human activities are compatible with the perpetuation of natural and beneficial values.

Although some values are specific to the riparian zone, most are shared with the channel and outer reaches of the floodplain within a dynamic functioning system. Floodplains in their natural or undisturbed state provide:

1. Water resource values--storage and slow release of floodwaters, water quality maintenance, and groundwater recharge;

2. Living resource values--fish, wildlife and plants;

3. Cultural resource values--open space, recreation, archeological and historical sites, scientific study, outdoor education, and natural beauty; and

4. Cultivated resource values: agriculture, aquaculture and forestry (Goodwin and Niering 1975; U.S.Water Resources Council 1978).

All of these values are important. However, the major weakness is that planning and evaluation procedures for development projects do not give equal consideration and treatment to these four categories of value. For example, living resources--such as fish and wildlife--and other common property resources and values, recognized under the public trust doctrine of law, frequently have not been given equal consideration and treatment, as called for by several federal laws.

The Fish and Wildlife Coordination Act of 1934 was the first major attempt to assure that living resources and their habitats are taken into account in planning and decision making on proposed water- and associated land-

development projects. In 1969, it was supplemented by the National Environmental Policy Act. This is a major directive to assure further that (1) inconsistencies in value recognition are identified, (2) a better balance is achieved among economic and ecological values, and (3) taxpayer dollars are invested in a more effective manner. It resulted in the most recent directive to realign cost-benefit calculation procedures used on public works projects. Misleading procedures used since the 1930s and perpetuated in various forms today are based on private goods and services exchanged in the market system. But, many values, services, goods and conditions important to society--such as those in floodplains and wetlands--are provided independently of the market system. Economists, planners, resource managers and others increasingly are recognizing that these values, largely beyond dollar expression, must be given careful attention and be taken into account in decision making to avoid their degradation or destruction. Court challenges emphasize the current struggle underway to recognize ecological values more fully.

All of us must recognize that the market mechanism of supply and demand is best for evaluating and allocating private goods. Likewise, it must be recognized that the market mechanism does not identify social values and benefits, and is inadequate to allocate them in the most effective manner. A different approach is required to maintain and manage common property resources, such as groundwater, detritus, habitats for living resources, fish, birds, insects, etc., important to continued functioning of ecosystems and to all citizens. The first step is to avoid misapplying benefit-cost calculations used on private goods in the marketplace to wetlands, floodplains and their variety of public values.

Current efforts underway to realign national water policies and procedures for planning water- and associated land-development projects must be monitored carefully. As part of each project plan, development agencies should identify, delineate and maintain important units of landscape that yield multiple values and benefits to society on a sustained basis. Basic ecological information should be incorporated in resource inventory and planning procedures to assure that preventive features are built into proposed project plans for each watershed, floodplain, riparian zone and wetland. This will ensure a continuing flow of public services, goods and values from the resource base, and minimize the need for mitigating unavoidable degrading impacts and losses.

A variety of actions are underway or being initiated to strengthen maintenance and management of riparian zones, floodplains, aquatic areas and watersheds. A few examples illustrate the enlarging efforts to adjust human-related activities to capabilities of the resource base at national, state and local levels.

1. National water policies and planning procedures are being revised.

2. State laws are being strengthened, to establish a more-balanced approach to water and land planning, development, and management. Shoreland laws and regulations have been enacted to guide developments.

3. Guidelines are being prepared by the U.S. Department of Interior to implement fully the Fish and Wildlife Coordination Act.

4. Public land administering agencies- such as the Bureau of Land Management with its 460 million acres, and the U.S. Forest Service with its 187 million acres--are in the process of issuing directives and guidelines to maintain, restore and manage wetland-riparian areas. Intensive management systems are to be designed for activities having greatest impacts on these areas, such as grazing, highway construction, timber management, mining (especially for gravel) and recreation. Two of the most challenging problems to be resolved are overgrazing of riparian areas and conversion of bottomland forests to row crops--the latter concentrated on private lands.

5. The Environmental Protection Agency and states are developing comprehensive environmental planning and management procedures to help the nation meet Clean Water Act objectives. One target is to identify and correct each state's major nonpoint water pollution problems through 208 comprehensive area planning. Correction of unchecked erosion in watersheds and floodplains holds promise for improving the quality of aquatic communities, including riparian zones. The pressing need is to apply the best management practices immediately, as outlined in final rules of the U.S. Soil Conservation Service for the Rural Clean Water Program (Federal Register 43(212): 50845-50866, 1 November 1978).

6. Guidelines for channelization of streams were issued recently and jointly by the U.S. Soil Conservation Service and the U.S. Fish and Wildlife Service to assure that channels and immediately adjacent riparian zones are maintained and not subject to inappropriate alterations. Hopefully, on-the-ground prescriptions will help ensure riparian vegetation that sustains adequate rates of biological activity in aquatic communities.

7. Clearing and snagging guidelines have been issued to resolve debates, and to incorporate biological and ecological dimensions in projects planned and carried out by development agencies, such as the U.S. Army Corps of Engineers and the Soil Conservation Service. Those for Chicod Creek in North Carolina and the Obion-Forked Deer River in Tennessee are recommended for your review. They are available from the Soil Conservation Service, the Corps of Engineers and the Fish and Wildlife Service.

8. Ordinances are being enacted in some localities to alleviate potential problems associated with incompatible uses of floodplains. For example, in February 1974, California's Napa County Board adopted an ordinance that requires a permit to alter a stream channel or embankment for a 50- to 100-foot wide strip landward from the top of each stream bank (Waananen, Limerinos and Kockelman 1977). The county may prohibit cultivation of farmland immediately adjacent to the banks of streams, thereby maintaining riparian vegetation, preventing bank erosion and collapse, avoiding accelerated sedimentation of the river, and maintaining habitats for living resources--particularly fish and wildlife.

These examples illustrate clearly that citizens increasingly recognize that riparian zones are integral parts of floodplains and watersheds. Full application of these guidelines will permit uses of the landscape for short-term advantage, while helping to avoid or minimize long-term degradation and destruction of riparian zones and other important landscape features. In our eagerness to effect landscape change, let us make sure it contributes to benefits and not to degradation and destruction of nature's functioning systems.

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Valuation of Riparian Habitats[1]

William King[2]
Michael Hay[3]
John Charbonneau[4]

Abstract.--This paper will look at two alternative approaches to valuing riparian habitat: the energy approach and the economic approach. Each of these approaches will be described and critiqued. The energy approach will be found totally lacking in utility to society for making informed judgments concerning riparian habitat. The economic approach, which will receive considerable attention, will also be found somewhat lacking in its ability to identify correct social decisions. A system of accounts will be suggested as a better solution to the problem of valuing riparian habitat.

INTRODUCTION

The purpose of this paper is to examine two alternative approaches to the valuation of natural riparian habitats. First, we will consider the energy or life support approach to ecosystem valuation. Then, the economic approach, sometimes called the component approach, will be described and critiqued. Finally, an improved approach to the problem of valuing riparian habitat and other natural environments will be suggested. No panaceas are offered in this paper, but we will recommend a systematic approach to the valuation of riparian habitat that will provide the decisionmaker with the objective information needed to make ecologically and socially informed resource use decisions.

[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

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THE ENERGY APPROACH

The problem of valuing natural riparian habitat is a subset of the larger problem of valuing natural environments. An approach to this problem that has received considerable attention recently is the energy approach. The energy approach has proven to be a path-breaking contribution to the understanding of ecosystem function, but ecosystem function is not the topic of this paper. This paper is about the valuation of a particular type of natural environment; thus, we will focus on the use of the energy approach for placing monetary values on natural environments. We will use a paper by Gosselink, Odum, and Pope as an example of this approach to monetary valuation[5]. Essentially, what Gosselink, Odum, and Pope did was to estimate the calories of energy produced by the primary production of a unit of the ecosystem and multiply it by a dollar value for a calorie.

The key to this approach is the premise that the dollar value of anything is based on the net energy it embodies. This premise leads to the conclusion that the ultimate objective of society is the maximization of net energy.

[5]Gosselink, James G., Odum, Eugene P., and Pope, R.M. The Value of the Tidal Marsh, Publication No. LSU-SG-74-03, Center for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana, May 1974.

Let's look at a few examples designed to illustrate an embodied net energy value system. I would argue that the current value of a 1955 Ford Thunderbird, a 1953 Chevrolet, and a 1979 Cadillac Seville should all be about the same since about the same amount of net energy went into their production. Under the embodied net energy value system, the value of a peregrine falcon would be very little. When asked why the approach to valuation was developed, the usual answer from the developers is that it is a way to measure the value of all things, both normal social goods and ecological values, with a single measure. When confronted with the problem of valuing a peregrine falcon, the usual reply is that the calories of energy must be weighted by quality. These two responses are inconsistent. How would we reconcile the fact that an acre of sterile Georgia beach front has tremendous ecological and economic value; yet, an acre of Piedmont forest produces much more net energy? And how would a mature bottomland hardwood ecosystem be valued? Would it be valued high because of the large amount of net energy it embodied, or would it be clearcut and replaced with a second growth forest that produces much more net energy? I have a set of rhetorical questions to ask:

1. Does anyone think that dollar prices at all accurately reflect embodied net energy rather than relative supply and demand?

2. Does anyone think that society should maximize net energy production rather than human well-being?

3. Does anyone believe that a system of value based on embodied net energy should be imposed on society?

One can imagine a truly colossal bureaucracy whose two functions in life were setting net energy values on everything exchanged in the society and increasing its own size, influence, and power.

In summary the embodied net energy value has several weaknesses:

1. The calculated values would not reflect society's values of the goods.

2. The approach would not result in a single undisputed measure of value.

3. If the values were used, they would distort the market allocation system.

4. It would be a very difficult and expensive job to measure net energy values for all competing goods.

THE ECONOMIC APPROACH

The economic approach to valuing natural habitats analyzes all the many uses to man of the habitat. It places market values on those uses that are traded in the market and tries to attribute values based on human behavior to those uses that do not have market values. The basic premise of this approach is that values are based on human preferences and that the objective of society is to maximize human well-being.

Let us see how we would go about valuing riparian habitat using the economic approach. First we will list the values of the habitat: 1) hunting and fishing, 2) observing nature and related activities such as hiking, canoeing, and environmental education, 3) option values, 4) existence values, 5) gene pool values, 6) scientific value, 7) flood protection, 8) sediment entrapment, and 9) other water quality improvement. There may be other values associated with any given parcel of riparian habitat or with all riparian habitats, but this list is sufficient to illustrate our points.

Recreation is one of the non-market uses that often produces substantial value. Methods for putting a dollar value on recreational activities such as hunting, fishing, and observing nature are being constantly improved. Two methods deserve our attention: One is the contingent valuation mechanism method, also called the bidding game or survey approach. The other method is the household production function or hedonic approach. The contingent valuation mechanism approach asks people to value public goods such as riparian habitats in a scientifically designed value choice situation. Although all the problems with this method have not been totally solved, progress has been made in overcoming possible sources of bias. Recent studies have been producing consistent and believable values for various kinds of environmental resources.

The household production function approach is based on the notion that households are producing as well as consuming units. Households put together inputs such as a car, a boat and trailer, tent and camping gear, fishing gear, some time, gasoline, and a good fishing river in order to produce a pleasurable fishing trip. The value attributable to the natural resources involved, the river in this case, is not equal to the total expenditure on the trip; rather, the value equals some part of that expenditure. The household production function approach uses certain mathematical relationships to estimate what part of the expenditure is attributable to the natural resources

themselves, or, indeed, any other input to the production of the trip. The household production function uses what economists call "revealed preference" information. That is, households reveal their preferences by the purchases they make and the activities they engage in. Use of revealed preference data makes the results more believable because they are based on observed behavior.

These two approaches are very compatible. The contingent valuation mechanism approach gives us information on the maximum amounts that people say they are actually willing to pay for a resource. The household production function approach gives us information on how much they actually did pay. Where the results of the two approaches are consistent, we can have considerable faith in those results and can use the cheaper, easier to administer contingent valuation mechanism approach to obtain additional related information. Values calculated using both approaches are based on variables describing the environmental characteristics of the habitat.

Option values and existence values are closely related. Option value is the value a person places on a resource in order retain the option of using it later. Each of the uses for riparian habitat presumably has an option value associated with it. Existence value is the value people place upon just knowing that the resource exists, even though they never plan to use the resource in question. Both option and existence values can be estimated using the contingent valuation mechanism approach; however, estimation of such values have been less successful than estimates of specific recreation activity values.

Gene pool value refers to the value that can be placed on a natural environment either because of the use to which some of its components could eventually be put or as a source of mutation that may later produce something of value to man. Gene pool values are very difficult to measure. For the most part attempts to measure such values have not been very convincing.

Scientific values refer to the value of a natural environment for scientific study and learning. For most habitats such values are probably small.

Riparian habitats can have significant value for flood protection. By allowing flood waters to spread out over a larger area, flood crests are both lowered and slowed. Valuing this type of flood protection is theoretically straightforward, but empirically difficult. Flood control construction agencies have developed sophisticated models to estimate the flood control values of their structures. Similar models could be used to value riparian habitat benefits. The key to accurate valuation is properly determining what society is really willing to pay for the flood control provided by the riparian habitat. That means doing a with and without analysis for the special case under study. This is commonly done for construction alternatives, but rarely for the services of natural resources.

Sediment entrapment is also a service of riparian habitats at least in time of floods. As is true of all the other uses of riparian habitat, sediment entrapment should be valued at what people are actually willing to pay for the services performed. If people did not mind more sediment in their water and if it caused no measurable environmental or equipment damage, then there would be no measurable value. But, where a willingness to pay for decreased sediment is demonstrated, for instance where there is a water quality standard that requires sediment removal measures or that would require such measures if sediment increased, then a value can be estimated.

Values for all the above uses of riparian habitats are additive under normal circumstances. Certain riparian marsh habitats can act as buffers for nutrient laden waters that flow through them. This can be an extremely valuable service of the marsh, but beyond some threshold level of nutrients, it will lead to a degradation in the quality and thus the value of the others uses of the riparian habitat. Once again, in order to value this use we must identify those thresholds and determine what people are willing to pay for the service actually rendered. In cases where thresholds are exceeded, we must also subtract the lost values in other uses caused by the infusion of large quantities of nutrients.

The values of the uses described so far would usually be calculated in terms of a certain unit of time, most often a year. In order to compare these values with alternative uses of the land occupied by the habitat, each of the values for each of the uses would have to be projected over a planning period. Then, the additive values for each future year would be summed, and the resulting stream of values would be discounted to obtain the present value of the land as natural riparian habitat. This present value can then be compared to the present values of other land uses in order to determine which has the greatest social value.

We believe that if this approach were applied accurately, many natural riparian habitats could compete effectively with other competing land uses. Not all uses in all places, but some uses in some very ecologically important places.

The economic approach to valuing habitat uses has the following significant strengths:

1. It is based on human values, and human values are the only thing that can realistically be used to make decisions about society's allocation of resources.

2. Most of the values used in the calculations are based upon the revealed preference behavior of people.

3. The result of the analysis is an objectively determined, single-valued number that is directly comparable with similar values for other uses.

4. The results from studies that are properly done are scientifically valid.

5. The measure used in this approach is widely recognized and accepted in our society.

The foregoing has been a rather glib recitation of the strengths of the economic approach to valuing riparian and other natural habitats. Unfortunately, the approach also has some weaknesses:

1. Future generations are poorly represented in the decisions of the present generation. To be sure, future generations are bequeathed vast quantities of capital for use in building their own consumption goods and services, but those future generations do not have the opportunity to vote on which capital goods are bequeathed to them nor on which resources were used in the capital good production. This is especially critical when we are dealing with a resource such as a riparian habitat that under many circumstances can retain its full value even at the end of any reasonable planning period.

2. The way in which preferences are revealed, if you will, the way votes are counted in the market place, is weighted by income and wealth. This may not be the way we want our votes on these crucial issues weighted.

3. Externalities, the secondary impacts of our decisions, are poorly counted by any known method.

4. The approach is expensive, although regional models that estimate values based on a series of variables that influence the value can spread the cost of expensive studies over a large number of projects and decisions.

5. The results are suspect by the highly vocal, highly effective conservation community.

6. Finally, what is perhaps the most severe criticism and the one that is hardest to overcome is the fact that the economic approach measures poorly the value of preventing irreversibilities and preserving unique features.

The economic approach, then, gives us a good and useful measure for decisionmaking, but it is a measure with some shortcomings.

AN INTEGRATED APPROACH

Let us propose four essential elements in measuring the values of riparian habitats and other natural land uses.

1. The measure must be an accurate reflection of human value. The economic approach is strong in this general area.

2. It must deal with irreversibilities and related problems.

3. It should be theoretically sound, empirically feasible, and politically acceptable.

4. It should result in a single quantitative measure.

Unfortunately, because of the complexity of the issues involved, element 4 is probably impossible to attain. Indeed, it seems sensible to say that because of this very complexity, decisions concerning preservation or destruction of a natural environment must, in the final analysis, be subjective.

Having described the essential elements of value measures for decisionmaking, we will now attempt to describe a system for producing and dealing with such measures. It seems that the system must consist of a series of four accounts for the different measures that together can contain the essential elements we described above.

There should be an economic account that displays values estimated by the economic approach described earlier in the paper. There should also be an ecological account to list both the ecological features of all

decision alternatives under consideration and to highlight any unique ecological features that appear in the area under study. There should be an account to take care of various kinds of social measures that for one reason or another cannot be included in either of the first two accounts. Finally, there should be an account in which to list certain political considerations such as impacts on local groups of constituents. A system such as this one would give the decisionmaker a comprehensive set of information that includes most everything needed to make an informed decision that is in the best interests of society.

Of course, in the Federal Government we already have such a system, Principles and Standards. So what's the big fuss? The problem is that no agency really uses P&S as a decisionmaking tool. P&S reports are completed regularly, but these reports are little more than rationalizations concocted to support decisons already made in the same old narrow way that most agencies have always made decisions. Riparian habitat and other valuable environmental resources are still being chewed up without ever really receiving a rational, objective hearing in the decisionmaking process.

What can be done? First, there are some technical problems that should be overcome. We need regional value equations for uses of both natural and man-made features. This will require adequate funding and a commitment to accomplish the task, but it can be done. Second, we need even better ecological measures. The Fish and Wildlife Service's Habitat Evaluation Procedures (HEP) seem to do a good job of ecologically analyzing what is on the ground, but a holistic measure is also needed. The embodied net energy measure seems totally inadequate for this task. Third, a more explicit, agreed upon basis for decisionmaking must be developed.

The challenge for the future is to apply P&S as an effective decisionmaking tool based on adequate value estimates.

Threatened and Endangered Wildlife: Recreational and Aesthetic Values[1]

Howard Brown[2]

The American Rivers Conservation Council is a national public-interest organization set up expressly to work for the preservation of a portion of what remains of our heritage of free-flowing rivers and associated riparian habitat. We work by lobbying the U.S. Congress, by harassing or supporting federal agencies--depending on what they are doing-- and by aiding and advising local citizen groups around the country in their river preservation efforts. So our mode of operation is quite different from the consulting reports, journal articles, and other work that many of you do. I want to use this opportunity to urge you all to get involved in efforts to preserve those pieces of the natural world that your expertise tells you are so important. I may not be capable of the rigorous scientific work that many of you are involved in, but you are all fully capable of exerting your voice in our political system, which has ultimate power over whether or not our grandchildren will be able to experience the beauty of natural streams and all the wonders of associated riparian ecosystems.

I am substituting for Jim Williams, of the Office of Endangered Species in the U.S. Fish and Wildlife Service, who was unable to come because of a death in his family. Jim is a good example of what I am talking about. He is a dedicated, highly competent scientist, but he also cares about the resources he is studying and is willing to devote time and effort to their preservation. He is now putting up with the hassles of bureaucracy to work for an agency that specifically has an endangered species preservation mandate. As a professor he devoted a lot of his spare time to preservation of rivers here in the Southeast.

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[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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This symposium is about riparian ecosystems: the water's edge, if you will. Many of the speakers will underline the biological importance of riparian areas. My charge is to address the broader range of values that come under the heading of recreation or aesthetics. I was just in an exercise last week with the Heritage Conservation and Recreation Service last week where we sought to set up a system for inventorying rivers which provided various values. Our categorization scheme included:

(1) boating or floating recreation of all kinds,
(2) fishing of all kinds, and waterfowl and other hunting,
(3) streamside activities such as hiking, picnicking, bicycling,
(4) geological features,
(5) historic, archeologic, and other cultural features,
(6) wildlife and botanical values, of course, and
(7) aesthetics in the basic sense of the values of scenery and a feeling of being in the wild.

I feel confident in asserting that, on all counts, the water's edge or riparian ecosystem is the most critical piece of our natural world. All of your work must make you aware of that in the biological sense. And if you think about the various aesthetic and recreational values, you'll also see that the water's edge is clearly prime habitat which if nothing else can be attributed to an almost magical effect free-flowing rivers and other natural water bodies have on the human spirit. The nice thing about all of these values, as suggested by the title of this talk is that they are truly non-consumptive and totally compatible with each other. Open space use of riparian lands is probably the ultimate in multiple-purpose management. Nature has clearly outdone any sort of scheme the engineers might come up with. Another nice thing is that all this value is concentrated in a narrow strip along the river or other water body. On a per acre basis there is a very high return on the

investment. If all that is not enough, we also have the engineering-type values such as flood water retention, ground water recharge, and water purification that come with natural flood plains and wetlands.

We now have a variety of federal programs which can help to protect our rivers and riparian areas, and there are many other proposals which could also help. These programs are fragile and vulnerable, however, as is the resource, and ultimately depend upon politics. If the public does not support them, particularly you the personnel who run them and you the scientists who know how important they are, the program won't work.

Dr. Jahn mentioned the National Environmental Policy Act and the Fish and Wildlife Coordination Act as bulwarks of conservation law. There is nothing magical about their existence, though. NEPA in and of itself does not protect any rivers or other natural areas. All that is really guaranteed is some jobs for some of you writing impact statements. Only if the agencies give genuine consideration to the impacts identified will anything happen. The best thing about NEPA is that it has given citizens who really care about a resource a chance to get their concern into the courts. The basic political support must be there, though. Congress recently included a provision in the Department of the Interior appropriations which exempted various water projects in the Colorado River Basin from NEPA. Unless our laws are defended from such abuse, they will be meaningless. The Fish and Wildlife Coordination Act is over 40 years old, but only now are we really getting into the battle to force the Corps and others to genuinely and fully mitigate fish and wildlife losses.

My particular niche is the National Wild and Scenic Rivers Act, which was enacted in 1968 to preserve a portion of our free-flowing rivers as a complement to water resource development. Rivers in the system are protected from water resource projects and, through very limited purchase of lands and scenic easements, form streambank development. The intention is to provide positive protection for worthy rivers and streams before they are threatened, rather than realizing what is to be lost as the bulldozers are ready to move or after its all over. Progress has been agonizingly slow, but we are encouraged by major additions this year.

Jim Williams' program is the Endangered Species Program, which intends to protect habitat areas for endangered species. But again Congress recently acted to prevent interference with business-as-usual river destruction in the name of progress and jobs for concrete manufacturers, and the program was seriously weakened. I am sure you are all aware that the impetus for this came from the Tellico case. That was obviously a last-ditch effort to stop a powerful force, but our laws won't do us any good if we are afraid to use them. Tellico clearly shouldn't have been built on economic, historic, fishing, and other grounds, but more importantly referrals under the Endangered Species Act were not resolved. We were hurt badly in the media-- "big dam stopped by little fish"-- partially because people like yourselves did not stand up to defend the importance of species preservation and the significance of habitats that are uniquely able to support a species.

This symposium is also about flood plains and wetlands. In May 1977, President Carter issued executive orders on both. These were intended basically to limit unwarranted flood plain development and wetland destruction by federal programs. Much of the destruction of rivers and riparian areas is funded by federal programs. Once again, these tools can only be as good as the people who use them, and then only if they have solid political support. We have had a flood plains executive order on the books since 1956, but it never really got put to use. The Army Corps of Engineers has had authority for non-structural flood control projects since 1974 under Section 73 of the Water Resources Development Act of that year (P.O. 93-251), but has made little use of it.

The National Flood Insurance Program is probably our most effective flood plain management tool, but also has a fragile base of support. It has recently been moved to the new Federal Emergency Management Agency. FEMA is supposed to have hazard mitigation as a primary mission, but will also have disaster relief and civil defense; flood plain management could easily get lost in the shuffle.

For wetlands, our best program is probably the Corps of Engineers Section 404 permit program for disposal of dredged and fill material. Interestingly, this did not develop from a conscious effort to protect wetlands, or even a magnanimous gesture to environmentalists. Rather, it grew out of a persistent effort-- which the Corps resisted-- to take advantage of an obscure 1899 statute.

As a last note, a potentially very important program is the President's proposed Heritage Trust Program, which would provide for a variety of protection measures for sites of all kinds having cultural, ecological, geologic, wild, and scenic values. It could also incorporate elements of the Nature Conservancy's natural diversity program which specifically seeks to preserve examples of various ecosystems for scientific purposes. This program

did not get anywhere last Congress, but could in the next with enough support.

You who are attending this symposium-- or reading these proceedings-- really do have an obligation to work for preservation of the riparian and other natural areas with which you work. You can make a difference. I would like to challenge this symposium-- individually and collectively-- to leave here resolved to take action to preserve what remains of our free-flowing streams and associated riparian habitats.

A Research Design for Understanding and Managing Complex Environmental Resource Systems[1]

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Abstract. A hierarchical framework for guiding the design of studies of complex environmental issues is presented, and emphasizes the importance of considering such theoretical concepts as controllability, realism and generality in such study designs. Controllability is a feature of experimental studies and is needed to establish mechanisms and suggest causal relationships; realism is a feature of observational studies and is needed to establish the "real world" importance of experimentally derived information; generality allows study conclusions to be extended to other areas and similar problems. Simulation modeling may play an important role in this area. A framework for integrating research results into resource management processes is also suggested. The above are considered in the context of a specific environmental issue concerning the role of submerged aquatic vegetation in Chesapeake Bay.

INTRODUCTION

In the past decade experience has demonstrated the interdependent nature of human (urban) activities and associated renewable resources. The need to use renewable resources wisely is reflected in such Federal legislation as the National Environmental Protection Act of 1970 and other state and local resource management programs. This interdependence or coupling of human activities and natural resources is especially evident in the coastal zone where numerous resource related activities occur together, often in conflict. The coastal interface between land and sea is characterized by productive natural ecosystems, many of which have direct influences on human economies through such activities as fisheries. The coastal zone is also a place where industrial, commercial and residential facilities tend to be focused. In fact, as Ketchum (1972) has pointed out, more than 50% of the population of the United States lives in the counties bordering the Great Lakes and ocean. This percentage has been increasing over the past century, and if it were to continue to rise conflicts in the use of riparian resources would be expected to intensify.

Estuaries, which are perhaps the most important of the coastal resource systems are characterized by complex, dynamic ecological communities. Within a single estuary a large variety of species occur over a seasonal cycle, particularly in temperate regions, while similarly a broad diversity of community types, habitats and species can be found along spatial gradients of salinity and water depths. When human activities are superimposed onto the natural estuarine regime they tend to influence natural temporal and spatial patterns. One of the primary ways in which human systems affect estuarine ecosystems is by modifying water

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quality.

The scientific community is of course dedicated to understanding the dynamics of such complex and changing environmental systems as estuaries while resource managers want to allocate available resources in a judicious fashion. In order to effect such judicious resource management, we must improve our understanding of how the components of natural ecosystems interact with each other and behave as a whole, and how perturbation from human activities alter ecosystem behavior. Moreover, this scientific understanding must be presented in a framework such that it is compatible with decision-making processes.

In the context of a specific environmental issue concerning the role of submerged aquatic vegetation in Chesapeake Bay, the purpose of this paper is threefold: (1) provide historical data which indicate possible reasons for an observed widespread decline of submerged aquatic vegetation and ecological ramifications of this decline; (2) suggest a hierarchical design for studying such complex environmental issues and; (3) propose a framework for integrating research results into resource management processes.

THE DECLINE OF SUBMERGED AQUATIC VEGETATION IN CHESAPEAKE BAY

The Chesapeake Bay is the largest estuary in the United States and because of its size, as well as its flushing and mixing characteristics, has been generally resilient to many natural and man-induced stresses. Despite the overall resiliency of the Bay, surveys done in the 1970s show a dramatic decline in submerged aquatic vegetation (SAV), an important food source and habitat for many species of estuarine animals. This decline in rooted aquatic vegetation might have been a minor concern if it had involved the disappearance of one or two species, but data collected by various agencies indicate that the majority of SAV species have been negatively affected and this phenomenon is essentially occurring throughout Chesapeake Bay. Data collected by Bayley et al. (1978) for the Susquehanna Flats area of upper Chesapeake Bay show that in the early 1960s there was a dramatic increase in eurasion watermilfoil, an invading species, and a concurrent decline in the dominant native aquatic species. After 1964 there was an increase in the abundance of the native species and a decline in eurasion watermilfoil which persisted until the early 1970s after which there was a precipitous decline in both species groups (fig. 1). All areas of Chesapeake Bay do exhibit such a clear pattern of decline but declines have been noted throughout the Maryland portion of Chesapeake Bay and have been particularly severe since 1972.

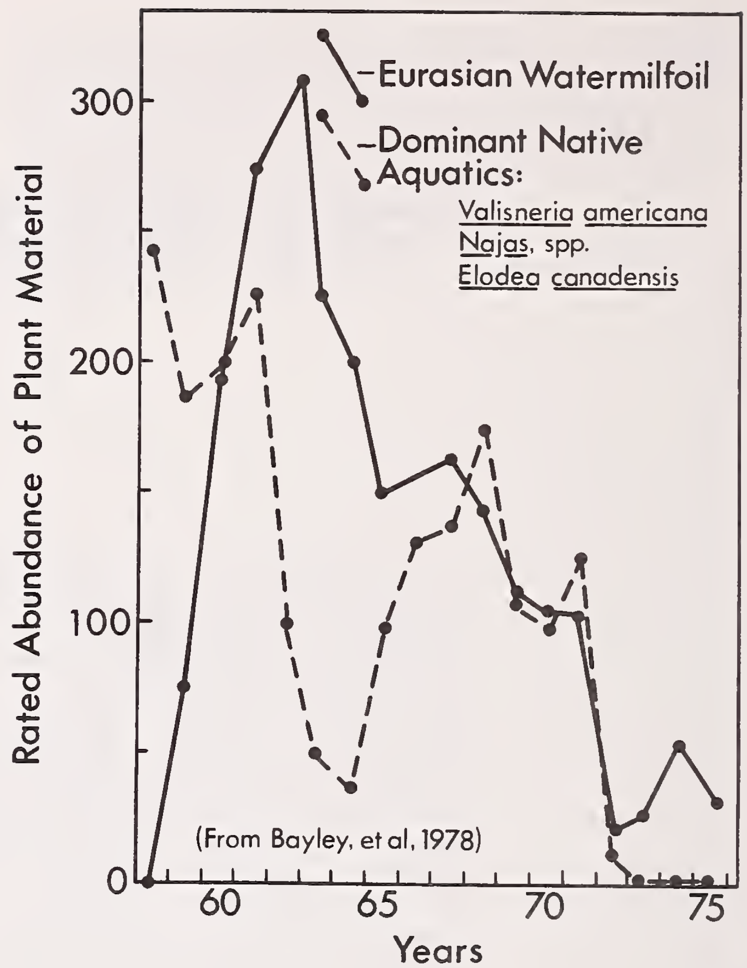

Figure 1. Historical population fluctuations of eurasian watermilfoil and of dominant native species. Data are from the Susquehanna Flats area of Chesapeake Bay.

Submerged aquatic vegetation is an integral part of an estuarine system such as Chesapeake Bay. Submerged macrophytes constitute the principle food source for waterfowl and some fish; they provide direct or indirect food and shelter for many of the small organisms that are eaten by fish and other predators; spawning activities of certain organisms require them; they reduce turbidity by precipitating fine sediments; and provide an important source of detritus. The assimilation of inorganic substances into organic compounds usable by organisms further enhances the importance of these plants as a link in estuarine food chains. Functioning as prime areas for hiding and breeding, this vegetation group provides surfaces for attachment of eggs. Also an abundance of animal life including insects, crustaceans, molluscs, fish and others find excellent feeding grounds in SAV communities (Baker, 1916). Submerged macrophytes also help stabilize sediments and reduce shoreline erosion. Bays with benthic flora have been shown to have relatively stable metabolism with less fluctuation in comparison with plankton dominated bays (Odum and Hoskin, 1958). SAV further functions in the estuarine nutrient cycle as both a potential source and

sink for dissolved forms of phosphorus and nitrogen (Clark et al., 1973). In Chesapeake Bay, Lipschultz et al. (1978) have estimated that in 1963 SAV contributed about 41 percent of the in-situ primary production. In 1975, SAV related primary production was estimated to be only 6 percent of the in-situ total.

Concern over the decline of SAV populations is related to both proven and suspected roles that this component plays in the Chesapeake Bay ecosystem. Several important changes in the ecological characteristics of the Bay have been noted and may be directly or indirectly related to changes in SAV. Some of these changes are well documented though as yet there has been little effort to synthesize this information into an overview of the Bay ecosystem. Several examples of important Bay species dependency on SAV are shown in figure 2.

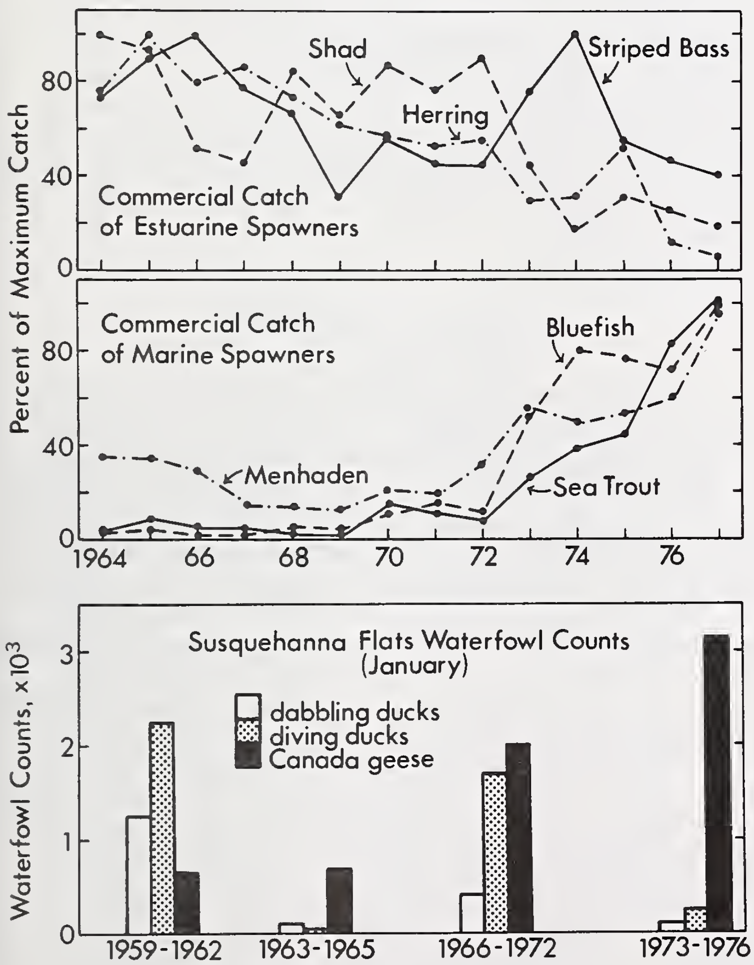

Figure 2. Historical trends in the commercial catch of estuarine and marine spawning fish in the Potomac River (Potomac River Fisheries Commission, 1978) and in winter waterfowl counts in upper Chesapeake Bay (Bayley et al., 1978).

The Chesapeake Bay is an important feeding area for migrating and wintering waterfowl. Changes in the availability of traditional food sources are regarded as a primary cause of Chesapeake Bay waterfowl population fluctuations (Perry et al., 1976), and it seems probable that the decline in the abundances of diving and dabbling ducks in Susquehanna Flats is related to the virtual disappearance of SAV from this area (fig. 1). On the other hand, the increase in abundance of Canada geese is most probably due to the fact that geese feed primarily in agricultural fields which are now a dominant feature of the Maryland Eastern Shore landscape. The commercial fish catch data in figure 2 suggest that there has been a decline in those species which utilize the estuary as a spawning and nursery area. The data given in figure 2 are from the largest tributary of the Chesapeake Bay, the Potomac River. For the most part, the decline in the catch of estuarine spawners and the increase in the catch of marine spawners coincides with the decline of SAV populations. The relationship of this phenomenon to SAV may be twofold, being related both to the habitat role of SAV in providing a refuge for young-of-the-year species, such as striped bass, herring, white perch and others and to feeding patterns. In general, there appears to be a switch from a detrital-benthic dominated food web to a simpler planktonic based food web. Considerably more work would have to be done to substantiate this relationship and at the present time this suggested relationship is speculative. While other examples of SAV contributions to ecosystem outputs are available, reasonably quantitative relationships between SAV and commercially important species are for the most part lacking and thus, at the present time, it is not possible to suggest the overall magnitude of ecosystem disruptions due to the loss of this ecosystem component.

A recent literature review (Stevenson and Confer, 1978) indicated that several water quality parameters including herbicides, turbidity and nutrients may be important factors involved in the decline of SAV in the Bay and that there may be complex interactions between these factors. Examples of water quality changes in the Patuxent River (another large tributary of Chesapeake Bay) and changes in the use of the herbicide atrazine in the coastal counties of Maryland are given in figure 3.

While these factors, particularly nutrients and turbidity, have been increasing in the Chesapeake and in specific areas have been shown to adversely affect SAV, the general situation does not indicate single one-to-one relationships between SAV declines and any of of these factors. For instance, SAV declines in one river system of the Chesapeake (Nanticoke River) appeared to be related to increases in turbidity. However, the Nanticoke had similar but lower suspended solid levels than several other nearby river systems which had higher SAV densities at a similar time. This suggests that it is difficult to attribute submerged acquatic vegetation de-

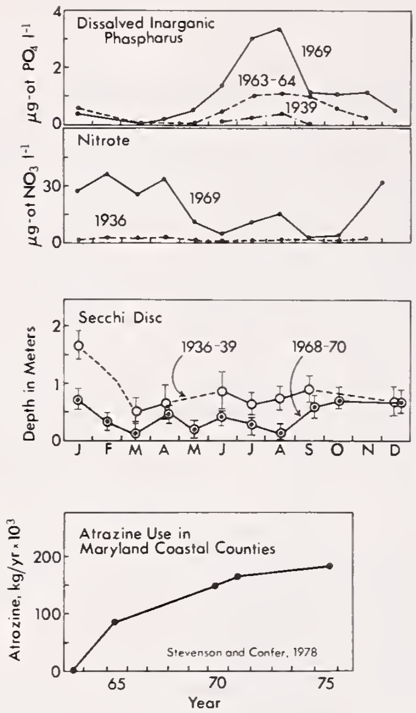

Figure 3. Changes in dissolved nutrients and turbidity in the Patuxent River, and in atrazine use in Maryland coastal counties.

clines to turbidity alone. Furthermore, measurements of community respiration and photosynthesis in a shallow embayment of the Choptank Estuary surrounded by agricultural land in which there was extensive use of herbicides and fertilizers indicated relatively low production despite extremely high nutrient concentrations (Stevenson et al., 1976). Comparisons of these measurements to others in similar temperate climates indicates markedly reduced production (Boynton et al., 1978). One possible explanation for low productivity at this site is that the area is under herbicide stress. While several conclusions have emerged, a number of questions remain concerning the relationship of the decline in SAV to changes in the water quality parameters.

RESEARCH DESIGN FOR THE STUDY OF COMPLEX ENVIRONMENTAL ISSUES

The framework used in the design of our SAV study was hierarchical and involved the concepts of realism, controllability and generality. As previously indicated there was a need to (1) determine causes of the decline in SAV populations (2) establish dependencies of both commercially important and other food chain organisms on SAV and (3) evaluate management options aimed at controlling factors leading to the decline of SAV.

Structure of SAV Research

To understand the dynamic response of submerged aquatic vegetation and the associated organisms to changing environmental conditions, it appeared necessary to focus research efforts at several levels. The hierarchical nature of the Chesapeake Bay as a regional system was conceptualized as indicated in figure 4, with models of each system and sub-system to the left and corresponding pictures to the right to indicate the particular scale of focus. These levels of organization included: (1) the Bay and its region; (2) pond micro-ecosystems as sub-systems of the Bay; (3) laboratory microcosms with component sub-systems from the ponds; and (4) physiological studies concerning effects of turbidity, herbicides and nutrients on SAV. Utilizing a hierarchical framework in research on such complex systems as the Chesapeake Bay provides a natural format for integrating information developed from detailed studies such as the physiological response of a particular SAV species to a specific herbicide into resource management policies at the largest scale. At each scale of study, models can be developed to clearly define the interactions being investigated, to indicate the way in which one scale is nested into the structure of the next and to generalize the results from one particular area of the Bay to other areas with slightly different characteristics. (Pattee, 1973; Weiss, 1969; Overton, 1977).

Integration of Research

In our SAV study and in many similar environmental studies there is the need to examine factors which may be causing ecological changes. An essential element of such studies must involve controlled experiments capable of identifying the effects of individual and combined factors on ecosystem components. As pointed out by Draggan (1976) and many others, the main drawback for such experimental studies is their lack of realism. In the case of our SAV studies, the need for accurate extrapolation of results from simplistic, controlled experiments to "real world" situations is particularly important because of the potential economic implications. In a hierarchy of studies such as that indicated in figure 4, larger scale research tends to exhibit greater realism while smaller-scale studies are more readily controlled for experimentation (Kerr, 1976). Inclusion of a suite of hierarchical scales provides for both realism and controllability within the overall research program.

The process of stepping from smaller-scale study to larger ones in the hierarchy helps to minimize the untested assumptions needed for the final extrapolation to resource management issues. For instance, as a test of the conclusions from experimental studies, phenomenological measurements can be made in-situ, that is, in the Bay itself. As indicated previously, the decline of SAV is not an isolated phenomenon limited to a few locales, but has occurred throughout the

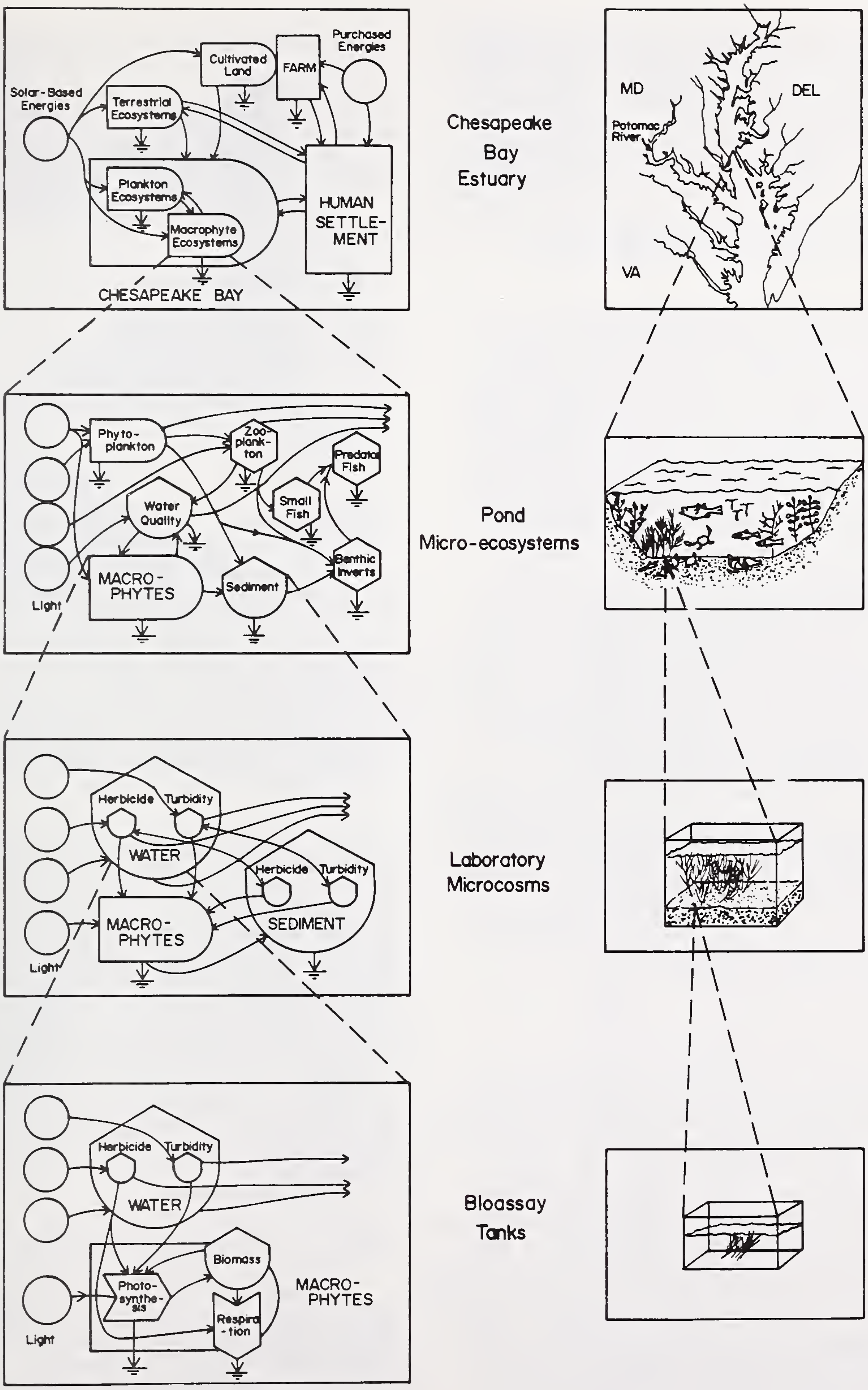

Figure 4. Conceptual models and diagrams showing the hierarchical nature of Chesapeake Bay as a regional system. Symbols used are from Odum (1971).

Chesapeake Bay. Any research project attempting to investigate this SAV decline and its implications therefore, must be designed to deal with the general nature of this problem. Hence, this research project has been integrated into a hierarchical structure in a multi-phase approach to obtain the essential features of controllability, realism and generality. In the following two sections, issues of controllability, realism and generality are further discussed.

Controllability and Realism

Relative relationships between realism, controllability and generality are graphically indicated in figure 5. At the laboratory level of hierarchical study, controlled environments are used with experimental flexibility which is obtained at some sacrifice of reality. In this study they are used to examine questions related specifically to the causes of SAV decline. The pond micro-ecosystem component provides considerable reality, that is, similarity to the Bay itself, while also allowing some experimental flexibility. At this middle scale there is a balance between controllability and reality allowing investigation of both causation and ecological dependency. The next level of research, the field studies, by definition have a high degree of realism, but little controllability and they are designed here to investigate the dependence of various Bay species on SAV in-situ. Studies of regional implications of SAV decline as related to alternative watershed activities, are not meant to have an experimental aspect in the usual sense. However, various scenarios of real applicability to the Bay region can be evaluated using information developed from in-situ studies.

Generality

Generality is an important feature of large scale environmental research programs because there is almost always the need to apply specific study results to large scale phenomena. Figure 5 suggests that generality is greater in large scale studies than in small studies which seems intuitively obvious at least from a spatial point of view. It is also suggested in figure 5 that while each hierarchical level has its own inherent generality, generality can be extended with multiple experiments and simulation modeling. In our SAV study the generality of the microcosm studies was extended via multiple experiments using different herbicides, turbidity conditions, and plant species representative of different areas of Chesapeake Bay.

The field studies also have some degree of bay-wide applicability because sampling sites were selected that represent various Bay ecosystems. The regional study is, by definition, bay-

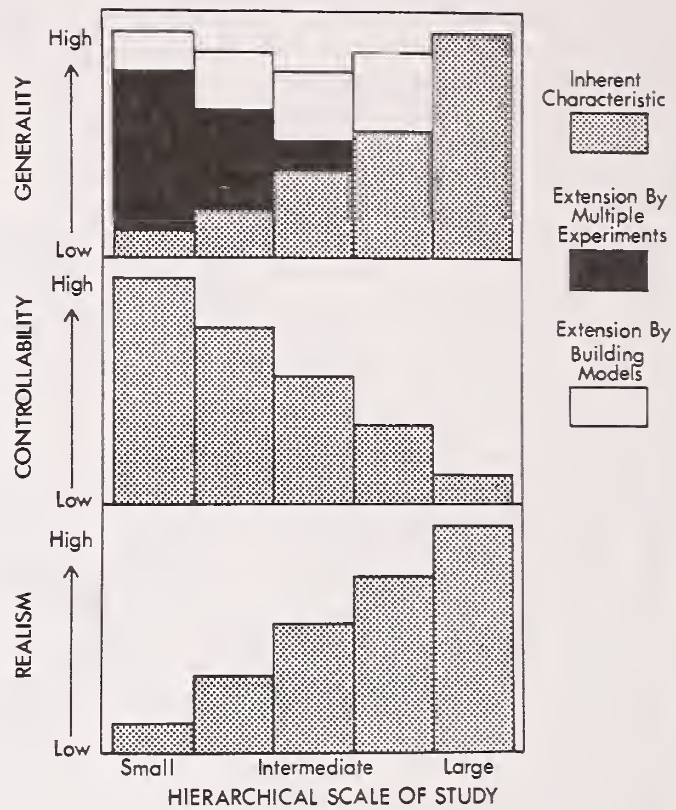

Figure 5. Relative degrees of generality, controllability and realism inherent at different scales of study in a hierarchical design. Methods for extending generality are also indicated.

wide in scope because it will examine the Chesapeake Bay region. While the micro-ecosystem studies (experimental ponds) have a good balance of controllability and realism, they sacrifice general bay-wide applicability to maintain a reasonable experimental design, that is, space basically constricts us to using about eight 1/8 acre ponds. Simulation modeling of these pond micro-ecosystems will to some extent compensate for this problem because models can be developed and calibrated to represent a range of salinity, temperature, herbicide and nutrient levels as well as sediment types and plant and animal species, to simulate a variety of bay ecosystems.

Simulation Modeling

To deal with complex regional environmental issues at the level of detail needed for conflict resolution, we suggest that a suite of hierarchical models be developed, similar, but more fully elaborated, that those given in figure 4. Hierarchies, with systems of subsystems of sub-systems, etc., may exist in nature as mechanisms for decreasing complexity, and increasing control and stability (Weiss, 1969). Similarly, groups of models for these complex systems, each dealing with a different sub-system can be developed. This allows us

tactically to view the vast complexity in an incremental fashion without losing the holistic perspective of the overall system. In this scheme, the outputs from the largest scale model provide inputs to the next smaller scale and so on. It must be remembered, however, that each time we aggregate a complex submodel into a single component of a given model of study, we lose resolution on the model's ability to mimic detailed dynamics of nature. As we aggregate mechanistic detail of interaction, model behavior becomes increasingly linear. System components should be aggregated together only if they have similar functional characteristics. Different biological populations, for instance, should be clustered together into a single model state variable only if they have similar characteristics of feeding, breeding and metabolic turnover-time.

In our SAV study we anticipate developing a hierarchical modeling scheme which includes models of (1) the entire watershed with highly aggregated representations of agricultural and urban activities and major ecosystem components (2) a model of Chesapeake Bay emphasizing land-water connections (3) a geographic sub-bay ecosystem which would include major ecosystem components aggregated by habitat or community type (4) a detailed model of a SAV dominated community and (5) a model of the physiological effects of herbicides, silts, and nutrients on SAV.

Practical Design Problems

While we are obviously in favor of such hierarchical designs as that presented here, there are some inherent problems which should be mentioned. Obviously, such multi-dimensional studies are expensive and require that a major fiscal commitment be made. Since such studies are large, and involve many areas of specialization, there is generally the need for more than one principal investigator and a large staff. We have found there to be a considerable cost in time, dollars and emotions based solely on the interaction required of all participants. An additional problem in implementing such studies is the simultaneous demand for participants to have a general background in ecology, for instance, plus specialized training in specific areas. Granting agencies and the scientific community are often skeptical of a generalist's ability to develop state-of-the-art expertise in the myriad areas addressed in a large study. One way of dealing with highly specialized areas is to contract these to established specialists.

Timing the completion of sub-programs is critical and obviously a risk. In our study, the results of microcosm studies guide the treatment variables and concentrations in the pond experiments. In turn, selecting the proper plant and animal densities for stocking in the pond micro-ecosystems depends on results of the field studies. The regional studies rely both on the results of our work and from concurrent and previous research programs.

FRAMEWORK FOR INTEGRATING RESEARCH RESULTS INTO RESOURCE MANAGEMENT PROCESSES

Assuming that such research establishes a reasonable understanding of mechanistic relationships and dynamic properties of natural resource ecosystems, such as Chesapeake Bay, the question remains as to how this information is to be used in managing these resources. At present there is no universally accepted approach to making this linkage and presumably numerous schemes are being used. We suggest that the following seven points (fig. 6) should be part of environmental evaluation procedures.

1. The first step is conceptualization of models for describing the problem. Models serve as formal definitions of the problem, as formats for data organization, and eventually, as tools for predicting the behavior of particular systems under various contingencies (step 5).

2. Next, alternative plans need to be selected. In the SAV study this may mean considering changes in land-water use practices.

3. Thirdly, an objective function must be defined. This amounts simply to a clear statement in words or mathematical terms (as in "operations research") of what the evaluation is going to try to accomplish. This may be the most fundamental but oft ignored step in the overall procedure. In traditional quantitative planning, objective functions described in economic terms include: maximization of net economic output; maximization of economic efficiency; or redistribution of wealth.

4. The next step is to assemble and/or measure scientific data to describe the systems being evaluated. This step often comprises the bulk of this work in the evaluation process. This step is equivalent to items given in the design portion of this paper. The models which were developed to define the study ecosystems,

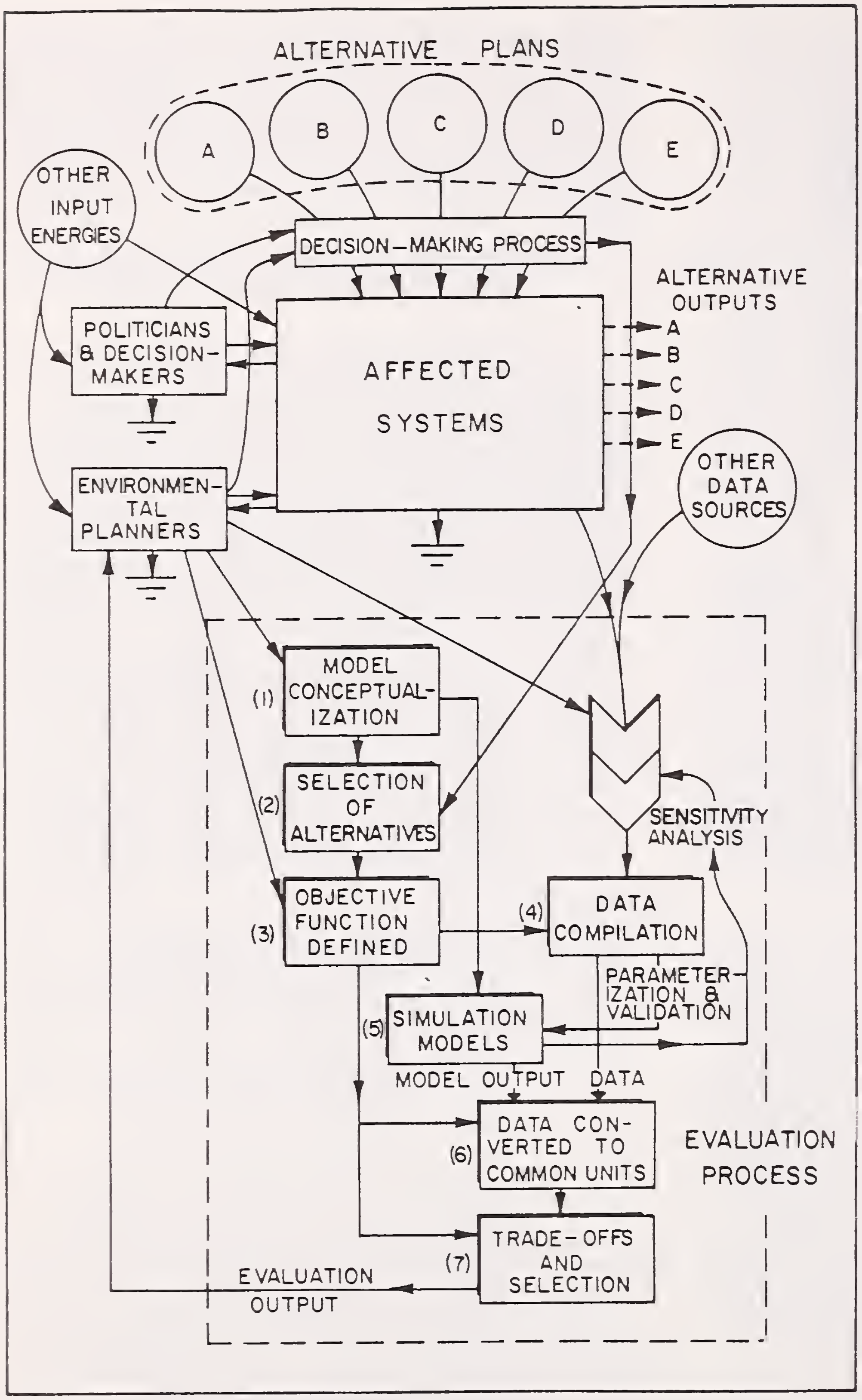

Figure 6. Generalized model of decision-making process suggested for environment evaluation.

are used to direct the search and research for quantitative data. Models tell the planner where the major "holes" are in his understanding of the systems, so that emphasis can be placed on these weak points for data assembly.

5. Next, mathematical models are developed from the conceptual models of step number (1), and these are used for computer simulation of ecosystem behavior. Model coefficients are evaluated from a portion of the data developed in step (4) and normative model output is validated against other portions of this data. Reciprocally, sensitivity analysis of the system model indicates which parameters have greatest influence on overall model behavior, again suggesting important

parameters to emphasize in the data compilation of step (4). These simulation models are the only objective tools available to the planner for forecasting what will be the effects of alternative plans on interacting ecosystems, before the alternative is enacted.

6. Pertinent pieces of assembled data and model outputs are converted into some common units of measure for comparing the effects of management alternatives. Traditional procedures (as in step 3) attempt to convert alternative benefits and costs into monetary units, but other approaches are also possible.

7. Finally, the benefits and costs of alternative plans are calculated and the tradeoffs are estimated quantitatively for the decision-makers. The plan which best fulfills the objective function (step 3) is considered best by this evaluation procedure.

The information flows implicit in the above seven steps are aggregated together within the dashed-line rectangle, and these flows interface with the decision-making process via the environmental planner (fig. 6). This environmental evaluation procedure as outlined here may be used to make scientific data available to planners, decision-makers and the general public in a digested, flexible and understandable format. The final decisions will most likely involve political factors as well. However, if society is to hold any hope for imparting the wisdom gleaned from scientific study into its resource management activities, planners must utilize evaluation techniques which encourage feedback of scientific data into the political process.

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Planning for Riparian Vegetation Management on the Sacramento River, California[1]

James W. Burns[1]

Natural resource values of the Sacramento River are being threatened by agricultural encroachment, and flood control, erosion control, and water development projects. Since 1975 the Resources Agency has been developing a resource management plan for the Sacramento River that includes preservation of native, riparian vegetation. The methods for preserving riparian vegetation that have been explored include zoning, modifying flood and erosion control construction and maintenance practices, regulating timber harvest, mitigating losses, acquiring land, developing a resource atlas to guide future planning, developing public awareness, and developing a waterways management plan for the river.

California has lost much of its riparian deciduous forests to urban development, agriculture, and flood control projects. Most of the recent concern over the demise of riparian forests in California has focused on the Sacramento River and its delta where the remnants of the once extensive gallery forests that lined the great river valleys of California are threatened. Before discussing our strategies for riparian vegetation protection, I think it is essential that I describe the land and water use and natural resource values of the Sacramento River so that you will understand the nature of the resource management conflicts.

The Sacramento River is California's largest river and it drains an area of about 27,000 square miles in northern California. Its annual runoff totals about 22 million acre-feet -- about one-third the total runoff from all of California's streams. The River begins near the slopes of the extinct volcano, Mount Shasta, and flows southward through the long, flat Sacramento Valley. The river meanders over a 300-mile course to the Sacramento-San Joaquin Delta and then drains into San Francisco Bay and the Pacific Ocean.

Dams have been built for water storage, flood control, and hydroelectric power on most of the Sacramento River's major tributaries. Shasta Dam, located on the main river near its headwaters, is the principal dam of the U. S. Bureau of Reclamation's California Central Valley Project. Shasta went into operation in 1943 and stores about 4.5 million acre-feet of water. About six million acre-feet are released each year from the dam to downstream areas. Not all of this water stays in the river, however. Several million acre-feet are diverted for agricultural, domestic, and industrial uses along the way. An extensive irrigation system has been developed in California to supply the needs of agriculture, and water from the Sacramento River is stored and conveyed to water deficient areas in central and southern California through this system.

Agriculture is big business in California, and within the Sacramento River Basin there are over 1.5 million acres of irrigated cropland. About 70 percent of this land is irrigated with Sacramento River water. These lands produce rice, cereals, fruits, nuts, and row crops that have an annual value of over $1 billion.

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The Sacramento River Basin also produces 1.6 billion board feet of timber (32 percent of all of California's timber products) each year and over 10.5 million tons of sand and gravel are mined from the basin each year. Most of the timber comes from conifers (douglas fir, true firs, pines, and incense cedar) that grow in the higher elevations of the basin. The trees that grow along the Sacramento River and its delta are predominantly cottonwood, willow, sycamore, valley oak, alder, ash, box elder, and black walnut. Some of these are harvested commercially for wood chips and lumber, but they make up only a small percentage of the annual timber harvest in the basin. Except for a few major urban areas, the Sacramento River Basin is sparsely populated. The Basin constitutes 17 percent of the State's land mass, but it contains only 7 percent (1.5 million people) of California's population.

The Sacramento River is important as a recreational resource. Its delta with its numerous channels and sloughs is rich in fish and wildlife and provides about 700 miles of boating water. The upper river is also popular for boating, fishing, hunting, and nature study.

The Sacramento River and its tributaries support important sport fisheries for king salmon, steelhead, and striped bass. Annually, 300,000 king salmon and 40,000 steelhead enter the Sacramento River to spawn. There are over 1.5 million striped bass inhabiting the Sacramento-San Joaquin Delta and Sacramento River. King salmon originating from the Sacramento River also support an important commercial fishery in the ocean. About 500,000 Sacramento River king salmon are landed each year in the commercial fishery. The average value of these salmon to the commercial fishermen is about $10 million.

The wetlands of the Sacramento River Basin are important to the over five million waterfowl that use this part of the Pacific Flyway each year. The river's riparian habitat supports numerous other wildlife species -- bald eagle, song birds, blacktail deer, beaver, and river otter to name a few.

The floor of the Sacramento Valley was once a vast wilderness with riparian forests and other wetland vegetation along its river banks, in overlfow channels and flood basins. Today, only remnants of this wilderness setting survive, mainly as narrow bands of vegetation along a few river channels. Based on historical accounts, there were nearly 775,000 acres of riparian forests along the Sacramento River and its tributary streams in 1850. Today, probably less than 20,000 acres of the formerly extensive riparian forests remain.

Construction of flood control works and dams along the Sacramento River and its tributaries in the past 50 years have contributed significantly to the loss of the riparian forests. After the floodworks and dams were constructed, landowners responded to the belief that flood and erosion dangers on low-lying alluvial soils were reduced dramatically over historic conditions. They moved down into the flood plains, removed native vegetation, and converted the riparian jungles to croplands and orchards. This land conversion is still going on.

In 1975, we compared aerial photographs from 1952 to 1972 to determine the extent of land use changes that had occurred along the Sacramento River during the past 20 years. We were startled to find that 53 percent of the mature riparian forests that existed in 1952 had been removed and the land converted to agricultural uses. Riparian forests weren't the only natural resource that was threatened, however. The number of king salmon spawning in the upper river had declined by more than 50 percent. In addition, new water development projects were being planned for damming additional Sacramento River tributaries, new bank riprapping projects were before Congress for authorization, a recreational boating trail was in the offing that could put campgrounds in key wildlife habitat areas, farmers were accelerating the rate at which they were ripping out riparian forests and leveling land for agricultural uses, and the market for hardwood chips had increased to a point where it had become profitable to cut riparian hardwood forests.

Some of these actions were the creation of, or were supported by, departments and boards under the jurisdiction of the State of California's Resources Agency. Still other departments -- such as Fish and Game -- were responsible for protecting the resources that were in danger.

It was obvious that it was time to take corrective actions and to coordinate the activities of the state agencies involved in the problems. Consequently, the Secretary for Resources established the Upper Sacramento River Task Force in the Fall of 1975 to solve the acute resource problems that were centered primarily along a 170-mile section of the river below Shasta Dam.

The initial Task Force was made up of the state agencies within the Resources Agency that have jurisdiction over activities that affect fish, wildlife, recreation, and aesthetic values of the Sacramento River. These agencies include Fish and Game, Water Resources, Parks and Recreation, Navigation and Ocean Development, Wildlife Conservation Board, Reclamation Board, Water Resources Control Board, and State Lands Division.

Soon the Task Force was enlarged to include federal and local agencies since their programs are tied closely to those of the state. The federal members include the Bureau of Reclamation, Corps of Engineers, Bureau of Land Management, Fish and Wildlife Service, and Heritage Conservation and Recreation Service. Local representatives include members of the boards of supervisors from the five counties bordering the upper river -- Shasta, Tehama, Glenn, Colusa, and Butte. Later, the Task Force was enlarged to include special interest groups -- the Sacramento Valley Landowners' Association and conservation groups (Audubon Society, Riverlands Council, Sierra Club, and Nature Conservancy).

The objectives of the Task Force are to coordinate intergovernmental activities and to take actions to ensure the protection of the fish, wildlife, recreation, and aesthetic values of the river while considering the other beneficial uses of the river and adjacent lands, for such uses as water conveyance and agriculture.

The Task Force has become a forum -- a place for the members to learn about and debate the values of projects, studies, and philosophies proposed by the various members. In addition, it acts as a catalyst for agencies and individuals to take actions to protect the environmental values of the Sacramento River.

The Task Force's first effort was to identify the problems and resource conflicts along the river. After identifying the problems, we developed a list of alternative actions which could be taken to decrease and possibly reverse the loss of riparian vegetation and the decline of king salmon populations.

The state members felt that riparian vegetation could be protected by making local governments aware of the problem and seeking their assistance in controlling the removal of riparian forests. We drafted a model, county general plan element, and ordinance that would bring the removal of riparian vegetation under a permit process. Under this ordinance, anyone wishing to remove vegetation within 150 feet of the river would first have to obtain a permit from the county planning commission. Permits could only be issued when the proposed activity was found to be compatible with the policy of the county ordinance and general plan. In issuing permits, the commission could place modifying conditions upon the activity in order to protect as much riparian vegetation as possible. We gave copies of these models to the five county boards of supervisors and asked them to adopt similar regulations, or to review and comment on the models. Unfortunately, only the northern-most county adopted a riparian vegetation protection ordinance. Three of the counties flatly rejected the idea of any type of regulation and another established a committee to evaluate the ordinance -- that was over two years ago, so it's unlikely that any of the other counties will pass an ordinance, unless future state legislation mandates it. The reason most commonly cited by county officials for not adopting an ordinance was that it would infringe upon the riverside landowners' property rights. Instead, the county officials said they favored a program of acquiring riparian parcels in fee title, easement, or lease, but only from willing landowners.

Next we asked the U. S. Army Corps of Engineers to evaluate its bank protection and levee maintenance projects to accommodate vegetation protection and to mitigate the loss of vegetation caused by their projects. Corps' regulations up to that time required that vegetation be stripped from banks and levees to facilitate inspection for erosion. Several meetings were held to discuss levee maintenance procedures and alternative methods of bank protection. Some progress has been made in this regard and I will discuss it later. Unfortunately, the Congressional authorizations for the Corps' bank protection projects do not include provisions for mitigating the project-caused damage to riparian vegetation and wildlife. Consequently, no federal money has been available for this purpose. Earlier this year, the Corps asked Congress to authorize mitigation for the Sacramento River Bank Protection Project. For that project, the U.S. Fish and Wildlife Service and the State of California proposed acquisition of riparian lands in fee title or environmental easements and the revegetation and management of the lands acquired. The mitigation costs would be shared -- one third paid by the state and two thirds paid by the Corps. At this stage, I don't know how successful we will be, since there is some disagreement with the Corps over the amount of mitigation

that should be provided. We want the loss of all the vegetation destroyed by the project to be mitigated; conversely, the Corps says that some of the vegetation would have been lost anyway through bank erosion or would have been removed if proper maintenance had been enforced by the state. Their opinion is that this vegetation should not be included in the mitigation.

The Corps has initiated a Sacramento River and Tributaries Bank Protection and Erosion Control Investigation. The purposes of the Corps' study are to: "(1) determine the federal interest in, and responsibility for, providing bank protection and erosion control; (2) study alternative means and the feasibility of providing a comprehensive program to stabilize the streams, protect the levees and banks, preserve riparian vegetation, wildlife habitat, and aesthetic values, and provide outdoor recreation opportunities along the river, considering intangible environmental values as well as economic benefits; and (3) select and recommend the best and most balanced plan of improvement, provided that such a plan is found feasible." The study was authorized in 1970, however, funds were not appropriated until 1977. The total study will cost a little over $1 million and it is to be completed in 1982. We have asked the Corps to include the following elements in their investigation:

(1) Evaluate the results of past bank protection efforts. (Some engineers suspect that riprapping banks does not dissipate the erosion power of the river and that the rock work simply directs the flow across the river to erode the opposite bank. Under this theory erosion doesn't end until the whole river is rock lined.)

(2) Determine the relationship between releases from Shasta Dam and erosion, and the probability of reducing erosion by altering releases from the dam. (Landowners claim that the operations of Shasta Dam for water supply and hydroelectric power have resulted in higher spring and summer river flows and greater fluctuations in river stages. This, they claim, is accelerating erosion by alternately wetting, drying, and undercutting the banks.)

(3) Predict future erosion patterns along the river.

(4) Evaluate nonstructural alternatives. (Would it be feasible to acquire easements along the river and allow the river to meander freely within a given width and apply bank protection only when the river reached a certain point?)

(5) Develop bank protection techniques and mitigation measures that minimize detrimental impacts on water quality, fish, wildlife, and scenery. (Would setback levees be a feasible technique?)

(6) Develop specific criteria for determining where bank protection should be applied and how priorities should be established.

In some recent bank protection work by the Corps under the Chico Landing to Red Bluff Bank Protection Project, the state established mitigation as a precedent-setting element of the project. The State Reclamation Board required the landowners to grant free conservation easements in return for bank protection. For areas already in agriculture a 30-foot easement width was required wherein native vegetation would be re-established, and for areas still supporting native riparian vegetation an easement width of up to 150 feet was required. The conservation easements will assure that no future development will encroach onto the top of the banks that receive rock revetment. Additionally, the Corps agreed to amend its bank protection maintenance manual to allow some native vegetation to grow in the rock revetment.

The State Reclamation Board -- the state agency having jurisdiction over land use within the Sacramento River's designated floodway -- recently signed an agreement with the Corps giving the state a more direct role in selecting and treating future bank protection sites. This should insure that only those sites that fully warrant bank protection will be treated. The members of the State Reclamation Board have made some other advances in riparian vegetation protection. Prior to 1975, few of the Board members showed concern for riparian vegetation. They saw it as a hindrance to flood control and they did not recognize its environmental values. The new Board has adopted the policy "that all activities carried out under its authority and under its permits give recognition to the value of riparian vegetation to the general welfare of California and that all practicable steps, consistent with the primary flood control purpose of these activities, be taken to preserve and encourage riparian growth". Along these lines, the Reclamation Board recently identified 38 sites, encompassing 4,100 acres, along an 81-mile stretch of the Sacramento River for retention of riparian vegetation. The vegetation is to be retained because of its value for stabilizing the river channel,

protecting levees from wind driven wave wash, reducing bank erosion, assisting in maintaining hydraulic control of the river, and protecting the banks from high velocity flows.

The State Secretary for Resources, State Reclamation Board, and State Water Commission have all asked the Corps and California Congressmen to have site specific environmental impact statements prepared for any future bank protection work on the Sacramento River. In the past, the adequacy and timeliness of the Corps' statements have been questioned. These new statements would not only have to be site-specific but would also have to address accumulative impacts of the bank protection work. The Secretary for Resources has also urged Congress to authorize mitigation as an element of the Chico Landing to Red Bluff Bank Protection Project and any other future bank protection projects. The cost of such mitigation would be borne by the bank protection projects.

Our next effort was to ask the State Board of Forestry to regulate timber harvest in the riparian lands of the Sacramento Valley. At present, a landowner can remove an entire hardwood forest in the Sacramento Valley without obtaining any permits other than a land leveling permit that may, or may not, be required by the County. Land conversion and timber harvest are regulated by the State Board of Forestry in other timberlands of the state and vegetation in stream environment zones is protected by the Board's regulations. The Board of Forestry should designate the riparian lands of the Sacramento Valley as "timberlands" and designate riparian tree species as "commercial species" so that the state can review plans and set standards for such activities. A proposal to the Board of Forestry is under review by the Department of Forestry, and I hope we can make a proposal to the Board in the near future. Our major hold-up has been that the Department and Board see this as an effort to preserve trees rather than to regulate timber harvest for sustained yield. The Board is primarily concerned with the harvest of coniferous trees and the Department of Forestry feels that its efforts should be centered on the species that make up the bulk of California's timber products. We are now gathering further evidence to show the Board that our concern is not only for the preservation of riparian vegetation and wildlife habitat, but also for fire prevention, erosion control, water quality maintenance, and sustained forest productivity, all of which are responsibilities of the Department and Board when associated with commercial timber operations.

Our State Department of Parks and Recreation and the State Lands Commission are cooperating with the U. S. Bureau of Land Management to determine state and federal ownerships along two 15-mile stretches of the upper Sacramento River. We have evidence that some of the land which has been converted to farmland may actually be state or federal land. Identification of public lands will improve public access to the river and will eventually result in the re-establishment of some native riparian vegetation.

Some key parcels of riparian vegetation have been purchased by the State Wildlife Conservation Board and numerous other parcels have been acquired by the State Reclamation Board as mitigation for flood control and erosion control projects. Funds to purchase additional interior wetlands and riparian habitat are still available from various State Bond Acts since some of the money allocated for these acquisitions remains unspent. In addition, state funds for acquiring riparian habitat can be requested from the state's Environmental Protection Program Fund that receives revenues from the sale of personalized auto license plates.

Unfortunately, having funds for acquisition doesn't ensure that such acquisitions will be completed. For example, the Wildlife Conservation Board has been unsuccessful in acquiring fee title or easements to some key riparian parcels along the river. The Department of Parks and Recreation also has had difficulty in trying to acquire development rights to certain riparian lands in the Sacramento-San Joaquin Delta. Most of our state departments and boards have a policy against using their powers of condemnation. Fortunately, some private conservation groups, such as the Nature Conservancy, are also interested in acquiring land along the river and landowners appear to prefer selling to them rather than to the state -- primarily because the landowners fear that public ownership will allow public access with trespassing, littering, and vandalism on their adjacent private lands.

Earlier this year the Task Force completed an Upper Sacramento River Environmental Atlas. It delineates areas of native vegetation, prime agricultural soils, recreation facilities, public lands, fish and wildlife habitat, commercial gravel operations, county zoning areas, bank erosion protection sites, diversions, designated floodways, areas subject to flooding, gaging stations, etc. With this atlas of resources and land use as a base, we plan to develop a waterways

management program for the Sacramento River. The Sacramento River plan probably will be similar to the waterway management plans that are developed for the state's wild and scenic rivers. The plan will set state policy for the Sacramento River and make recommendations to local governments, state agencies, and the state legislature on actions necessary to protect the river and its resources.

The Task Force is also publishing a series of issue papers that will be used as the base for developing recommendations for the state plan. One of the issue papers is titled "Diminishing Riparian Vegetation". Recommendations in that issue paper include: acquisition of riparian lands in fee title or easement, legislation to mandate county zoning to protect riparian vegetation, regulation of riparian logging in the Sacramento Valley by the State Board of Forestry, development of a waterways management plan, and reforestation.

The reforestation program is the most exciting recommendation and one that needs to be explored more fully. I'm hoping it can be tied into a program of developing biomass as an alternative source of energy for California. A future market could develop for hardwood fuels, and tax incentives could be used to encourage landowners to plant native trees. The new forests would probably have a harvest cycle of 20-or-more years and the harvest could provide habitat for wildlife if managed properly. Under this management, I would expect a provision for the protection of stream environment zones and, thus, we would increase the abundance of trees next to the river. Careful implementation of this program would be essential because there could be an immediate, short-term demand for the wood that would result in the cutting of existing hardwood forests without proper protection of the riparian zone and without provisions for restocking. This threat may be a good selling point to the Board of Forestry on why the logging of riparian forests should be placed under the regulatory provisions of the State Forest Practices Act.

Under the leadership of conservationists, a bill was developed and passed this year in the state legislature that appropriates funds to the Department of Fish and Game to: (1) determine the status of riparian vegetation in the central valley and desert areas of the state, (2) compare the historical and current status of riparian vegetation, and (3) make recommendations to the legislature on how this resource should be managed.

County supervisors and timber, agriculture, and grazing interests opposed the bill. They fear that once that status of the native riparian vegetation is known, legislative action will be taken to regulate landowners' activities along stream courses. I see the bill as the vehicle to request legislation to protect the remaining riparian vegetation areas in the state.

A major obstacle in our efforts to protect the natural values of the Sacramento River has been the riparian landowner. Agriculture has clout in local, state, and national government. Flooding and erosion of agricultural lands, and protection of private property rights are issues that command an instant response from many government officials -- especially in California. Some congressmen are quick to introduce public works projects to protect agricultural lands from flooding and erosion, and supervisors and some legislators are quick to agree that the land must be protected by structural means. Little or no consideration is given to the impacts such projects have on fish, wildlife, and recreation. The nonstructural alternatives of floodplain management, such as strong local zoning, are ignored as is the question of whether it is proper to spend public funds to underwrite unwise uses of the flood plain by private interests. When an effort is made by a government agency to acquire property for mitigating the impacts of such flood and erosion control projects, the issue of private property rights is raised by the landowner. Because of political pressures, most public agencies submit to a compromise that does little to protect the fish, wildlife, and other natural values that are adversely impacted by the project. Consequently, an additional loss occurs to riparian vegetation and to the wildlife, fish, and recreation dependent upon that vegetation.

We are hopeful that our efforts will be successful, but public awareness and political activists are needed to convince legislators, county supervisors, and the U. S. Army Corps of Engineers that riparian vegetation must be restored and protected. Symposia, news articles, and television specials have focused on the problems of the Sacramento River and these are helping build public awareness and support in California. However, we still need to develop further a broad public support for the protection and management of riparian vegetation. Only then will we have the political clout to achieve our goals.

Riparian Woodlands in Jeopardy on Northern High Plains[1]

Charles E. Boldt, Daniel W. Uresk, and Kieth E. Severson[2]

Abstract.--Cattle damage is the most conspicuous of several impacts threatening the persistence of stringer woodlands scattered through the region's upland draws. Preliminary results of stop-gap research suggest that declining stands may be revitalized, and habitat values enhanced, by combinations of fencing, partial cutting of trees, and underplanting.

"Bright, clear sky over a plain so wide that the rim of the heavens cut down on it around the entire horizon... Could no living thing exist out here, in the empty, desolate, endless wastes of green and blue?... If life is to thrive and endure, it must at least have something to hide behind!"

O. E. Rolvaag
Giants in the Earth

A century has passed since Rolvaag's pioneer woman was overwhelmed by feelings of vulnerability on the vast, windswept expanses of the northern Great Plains. Much has changed since then, but the no-place-to-hide character of the country remains. And its warm-blooded residents still need protection to survive.

Visitors to the northern Plains, past and present, have been apt to call the rolling uplands "treeless prairies." This may be roughly descriptive, but it is not quite accurate. In fact, native tree-shrub communities are widely present but remarkably unnoticeable, except from the air. The low visibility of these woodlands derives from their virtual confinement to moist, sheltered sites on the bottoms and lower slopes of grassland draws (fig. 1). Limited to such sites, they are both scattered and hidden.

Figure 1.--Segment of a typical tree-shrub stand in a draw on the Little Missouri National Grasslands, southwestern North Dakota.

These riparian-like, stringer woodlands, composed mainly of deciduous trees and shrubs, probably occupy less than one percent of the upland area, region-wide. Yet, because of their dispersion and make-up, they are believed to provide valuable, perhaps critical habitat diversity for both wildlife and livestock.

THE PROBLEM

Although largely subjective, there is considerable evidence that the woodlands of the northwestern, or High Plains constitute a vegetation type in serious trouble. (Severson and Boldt, 1978).

[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, Atlanta, Georgia, Dec. 11-13, 1978.

[2]Silviculturist, Biologist, and Range Scientists, respectively; Rocky Mountain Forest and Range Experiment Station; Boldt and Uresk stationed at Rapid City, South Dakota; Severson at Tempe, Arizona.

There appears to be no record of who first recognized the problem or where. In any event, by the early 1960's there was sufficient interest in the tree-shrub associations of the "woody draws" in southwestern North Dakota to incite some small-scale investigations of the composition, structure, and condition of a few representative stands (Nelson, 1961; McKenzie, 1973). As the results of these early studies became known to range resource managers and scientists, the woody draws gradually became the objects of scores of independent, informal evaluations of the windshield survey type, throughout the region. Subsequent casual exchanges of findings led to more deliberate and thorough examinations of the occurrence, status and value of the prairie woodlands. These efforts gained impetus and urgency with the passage of the National Environmental Policy Act of 1969.

The results, when finally pieced together in a series of agency and interagency workshops, conferences, and reports, in the early 1970's, revealed a worrisome composite picture of the situation. Many woody stands in the upland draws had already disappeared from the High Plains landscape and been replaced by stands of grass and forbs. Many more woody stands--perhaps most of them in some localized areas--were clearly in a serious state of decline. Here and there, a few stands persisted in healthy, productive condition.

The latter stands are characterized by a thrifty, moderately dense stand of trees dominating a dense, vigorous, mixed stand of shrubs. Such stands usually have a site-protective litter and duff layer reminiscent of hardwood forests in good condition. There is usually some evidence of on-going tree and shrub reproduction.

The more prevalent, declining stands, in contrast, usually have a decadent tree overstory in advanced stages of breakup, with only scattered remnants of the associated shrub stand. The site is typically devoid of duff and litter; tree and shrub seedlings, suckers, and sprouts and rare; and the groundcover, if any, is herbaceous (fig. 2).

High Plains land managers were understandably alarmed by the realization that an entire cover type--particularly one of limited extent and presumably high value--was seemingly threatened by extinction. They called on research for help.

Figure 2.--Interior of a declining, heavily-grazed, woody draw stand on the Little Missouri National Grasslands, southwestern North Dakota.

PROBLEM ANALYSIS AND PLAN OF ATTACK

Field examination of many deteriorating stands by a silviculture-range scientist team--generously assisted by many others--suggested that a wide assortment of destructive factors were at work in the failing prairie woodlands. Some factors were boldly evident, others were obscure.

Trees in many stands appeared to be nearing the end of their lifespans, which tend to be shortened by the rigors of the northern Plains environment. It is well known that reduced vigor and growth of senescent trees makes them especially vulnerable to damage by insects, diseases, and mechanical stresses. All of these agents were clearly impacting the majority of trees in the declining stands examined. Virtual absence of seedling reproduction by failing trees could not be attributed to senescence alone, but there were strong hints that insect depredations might be reducing seed production.

The types of damage sustained by lost or failing shrubs were more difficult to identify. Clump remnants often showed evidence of prolonged heavy browsing and mechanical damage. If insects and diseases were contributors, it was usually not apparent. Lack of successful reproduction by sprouting or suckering was usually obvious but not easily explained.

All troubleshooters noted an almost invariable connection between woody stand deterioration and concentrated use by livestock, primarily cattle. Scientists with experience in Plains forestry saw the effects as analogous

to the responses of shelterbelt stands of trees and shrubs to heavy livestock use. Thus, cattle--with their known affinity for shade to escape heat, wind, and insects--emerged as the most conspicuous factor in the syndrome of woody stand deterioration.

The search for causes also raised a host of intractable questions about the possible involvement of long-term trends of changes in climate, geology, hydrology, erosion, soils, and plant succession. Some observers wondered if prolonged protection of woody stands from wildfire might not be contributing to their decline. A few puzzled over the implications of replacement of free-ranging buffalo herds by confined livestock.

The fact-finding and problem analysis process was interrupted, after about a year, for interim decisions on research priority and direction.

From the scientific standpoint, we felt a strong need for fundamental information on the "whys" of woody vegetation decline, together with a solid assessment of the principal values of the woodlands in a grassland setting. Yet, we knew that such research would require a great deal of time--a luxury which worried resource managers could not afford. We decided that we could best serve the urgent needs of both the managers and the vegetation type itself by concentrating most of our initial effort on cultural measures to delay or reverse the decline process.

As a complement, we opted to continue to expand on-going research on use of High Plains habitat types by mule deer and other wildlife species.

WHAT WE DID

Having decided to invest our first efforts in a field trial of cultural measures for stand rehabilitation, we selected three treatments which seemed most likely to be both effective and practical.

Because use by cattle seemed so intimately associated with stand condition, we reasoned that the trials would not be complete without a test of fencing to exclude cattle. This was the first treatment chosen.

Observations indicated that many trees in existing stands were of sprout origin. Silvicultural experience has shown that sprout reproduction has a high survival-growth potential due to support from large, established root systems. Thus, felling of selected high-risk, low-vigor trees, to promote sprouting, was chosen as a second promising treatment.

Finally, it appeared that seed reproduction of trees and shrubs was an uncertain process in declining woody draws. On the other hand, transplanting of nursery stock--if properly done--is a relatively dependable way to establish woody plants in the Plains. So, we elected to include a test of underplanting of a few tree and shrub species as a supplementary regeneration method. Underplanting seemed potentially useful not only as a backup for natural regeneration by sprouting or seeding, but also as a way to enrich stand compositions with desirable species not currently present.

Location of Trials

We installed the trials in an area where failing stands were especially prevalent and managers were particularly concerned about the problem: The Little Missouri National Grasslands, Custer National Forest, in southwestern North Dakota. We selected a draw system in the upper reaches of the Magpie Creek drainage on the Medora Ranger District.

Vegetation

The draws contained typical, fairly continuous, and reasonably uniform stands of green ash (*Fraxinus pennsylvanica* March.) and American elm (*Ulmus americana* L.), with a shrub understory which included western snowberry (*Symphoricarpus occidentalis* Hook), Woods rose (*Rosa woodsii* Lindl.), spiny currant (*Ribes setosum* Lindl.), Saskatoon serviceberry (*Amelanchier alnifolia* Nutt.), silver buffaloberry (*Shepherdia argentea* Nutt.), common chokecherry (*Prunus virginiana* L.), American plum (*Prunus americana* Marsh.), hawthorn (*Crataegus* spp.), and raspberry (*Rubus* spp.).

The tree stand, in which green ash predominated, was essentially even-aged. Most trees were 60 to 70 years old. Average stand density was about 480 live trees per acre. The largest tree encountered had a d.b.h. of 16 inches; trees in the 3- and 4-inch d.b.h. classes were most numerous; 5- to 9-inch trees were most prominent. Dead trees, both standing and down, were scattered throughout the stands. Live trees generally looked decadent and non-vigorous.

Shrubby associates, except for the durable western snowberry and dense peripheral clumps of buffaloberry, appeared to be in as poor condition as the trees.

The sampled draws were located in two pastures of a three-pasture range allotment which, at the time of plot establishment, had been managed for two years under a deferred

rotation grazing system. Previous to the change it had been grazed season-long as a single pasture.

There was clear evidence of heavy cattle use throughout the stands. The reasons appeared to be the usual ones: The relative scarcity of woody cover; its natural attractiveness to cattle; and the juxtaposition of watering places and associated salting stations.

Plots and Treatments

Twelve rectangular plots of 0.2 acre each were established at scattered locations in the draw system where site and vegetation conditions were reasonably uniform and representative. Plots were randomly assigned to three replicate groups of four plots each. Within each group we randomly assigned one each of these treatments:

1. Cattle-proof fence;
2. Cattle-proof fence, plus partial cut of trees, plus underplanting;
3. Partial cut, plus underplanting with no fence;
4. No fence, no cutting, no underplanting.

Before treatment, a 100 percent tally was made of all live trees 1.0 inches d.b.h. and larger on all plots. Shrub and small tree stems were counted and their heights measured on five, 50-foot by 4-foot belt transects randomly placed on each plot.

On plots designated for cutting, about 40 percent of the trees were selectively marked and cut to open the canopy, stimulate sprouting, and eliminate the poorest of the growing stock. After cutting, 15 stumps on each plot were randomly selected as sources of data on sprout production and growth.

On the same plots, we underplanted, by hand, on herbicide-treated spots, containerized tree and shrub seedlings of six species: Green ash, Rocky Mountain juniper (Juniperus scopulorum (Sarg.), bur oak (Quercus macrocarpa Michx.), common chokecherry, American plum, and Russian olive (Eleagnus angustifolia L.). Twenty four seedlings of each species were planted in each of six partially cut plots, with species distributed randomly throughout a lattice pattern.

Fences were installed in late summer of 1975; cutting was done that fall. Seedlings were planted in the spring of 1977. After-treatment tallies and measurements of trees and shrubs, stump sprouts, and planted seedlings were made in late summer and fall of 1976, 1977, and 1978.

WHAT WE HAVE LEARNED

After only three years, results must be interpreted and reported guardedly, and applied with caution.

Results of Partial Cutting

Felling of nearly half of the overstory trees obviously opened the canopy, but we obtained no before-and-after measurements of canopy density. Cutting discriminated against and reduced the number of highly defective trees, many of which were rotten, broken, and snag-topped.

As expected, stumps of nearly all felled trees produced sprouts the first growing season and most retained live sprouts three years later (Table 1).

Table 1.--Production and growth of stump sprouts on fenced and unfenced plots in woody draws; Little Missouri National Grasslands, North Dakota

Item	Fenced	Unfenced
Stumps with sprouts, first year; percent	98	100
Stumps with sprouts, third year; percent	95	95
Average number of live sprouts/stump, third year	14	17
Average height of clumps, third year; feet	4	2
Average height, tallest sprouts, third year; feet	5	3

Protection from cattle browsing, or lack of it, made an important difference in how sprout clumps developed, but it did not have much effect on numbers of sprouts surviving after three years. Heavily browsed sprout clumps may or may not die off in the future. About 80 percent of the clumps were browsed on unfenced plots. Only about 15 percent were browsed on the fenced plots, presumably by deer.

Results of Underplanting

Our 1977 underplantings could easily have been a total failure. Only a few weeks after

they were made, the area was battered by a severe Memorial Day hailstorm. There was almost no precipitation during the rest of the growing season. Despite these unfavorable conditions, surprising numbers of planted trees and shrubs were still alive and growing at the end of their second growing season in the field (Table 2).

Table 2.--Survival of underplanted trees and shrubs on partially cut, fenced and unfenced plots in woody draws; Little Missouri National Grasslands, North Dakota

Species	Percent surviving[1]	
	Fenced	Unfenced
Green ash	21	29
Rocky Mountain juniper	96	90
Bur oak	90	69
Chokecherry	82	60
Wild plum	89	65
Russian olive	40	13

[1]At end of second (1978) growing season.

The relatively poor showing of native green ash seedlings (grown from northern Great Plains seed) was probably due to the condition of the containerized plants. Most had grown too large for the containers they were in, upsetting the top-root balance. Defoliation by hail, followed by prolonged moisture stress, was apparently too much for them.

The poor survival of the Russian olives cannot be explained; they were not overgrown like the ash.

The other transplanted trees and shrubs performed satisfactorily in the field to the end of the second season. Reductions in survival of unfenced seedlings were expected and appeared to be largely due to browsing and trampling by cows. For unexplained reasons, few of the juniper seedlings were either browsed or trampled.

Results of Fencing

Apart from the benefits to sprout clumps and transplants, the effects of fence protection, if any, were indistinct in the transect data at the end of three years. There were highly visible increases in the growth of understory grasses and other herbs in both the partially cut and uncut exclosures. Unfortunately, in our preoccupation with woody plants, we failed to measure responses of the herbaceous vegetation. The rank, unutilized grass stands present in 1978, however, showed strikingly the high levels of potential productivity inherent in these riparian-like, upland sites.

Oddly, the transect counts failed to show any solid indications of increases in shrub stand densities on either the fenced or fenced-and-cut plots, 1975 vs. 1978. Perhaps three years is too short a period to expect measurable density changes. Or, perhaps, the rank growth of grasses may have occurred at the expense of shrub proliferation.

There were, however, some treatment-related changes in height growth of shrubs and tree seedlings, 1975 vs. 1978 (Table 3).

Table 3.--Average changes in shrub heights on woody draw plots before and three years after various treatments; Little Missouri National Grasslands, North Dakota

Species	Ungrazed-cut	Grazed-cut	Ungrazed-uncut
	Percent	Percent	Percent
Western Snowberry	4	7	6
Woods rose	[1]48*	-10	--
Saskatoon Serviceberry	8	- 6	31*
Spiny currant	--	- 1	4
Green ash	177*	106*	2
American elm	620*	19*	58*
Western Chokecherry	69*	-20*	33*

[1]* indicates changes that exceeded ± 15 percent, hence were large enough to be judged biologically important. All values in table were adjusted to account for unexplained changes in height on grazed-uncut plots, then expressed as a percent of heights on grazed-uncut plots.

The most abundant shrub, western snowberry, did not show important changes in height due to treatments; nor did spiny currant. Excluding livestock grazing and reducing tree stand density increased the heights of Woods rose, green ash, American elm, and western chokecherry. Increases in heights of Woods rose and green ash seemed to be favored mainly by the reduction in tree density. Increases in heights of American elm and chokecherry, on the other hand, seemed to be more closely related to elimination of grazing.

In general, after three years, shrub densities showed no effects of treatments. Height data indicate that positive or negative effects are highly dependent upon individual shrub species. It appears that a longer time period will be required to fully assess the possible benefits of protection from grazing by livestock and reduction of tree densities on the shrubs that occur in woody draws.

SUMMARY

The deciduous tree-shrub type of the woody draws appears widely threatened by multiple impacts, among which cattle damage is the most visible if not the most detrimental. As a first attack on the problem, field trials were installed to find out whether selected cultural measures might effectively reverse the syndrome of stand deterioration. After only three years, results of the trials are inconclusive, but there are good indications that: 1) Moderate partial cuts will stimulate sprout regeneration of green ash and American elm and promote height growth of Woods rose and green ash seedlings; 2) At least a few kinds of tree and shrub seedlings can be successfully transplanted under partially-cut stands; and 3) protection from cattle grazing improves survival of most underplanted trees and shrubs, development of tree sprout clumps, and height growth of chokecherry and American elm seedlings.

As yet, it is uncertain how the treatments either alone or in combination, will affect shrub stand densities and seed reproduction by trees.

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Tree Plantings - A Diversified Management Tool for Reservoir Shorelines[1]

A. Leon Bates, Eugene Pickard, and W. Michael Dennis[2]

Abstract.--Shoreline plantings of baldcypress [Taxodium distichum (L.) Richard] and other water-tolerant tree species have been established since 1935 within the fluctuation zone at selected sites within the TVA impoundments in the Tennessee River watershed. Although initial studies were designed primarily to evaluate the impact of tree plantations on mosquito breeding habitats, the plantings were found to be a potentially valuable tool in managing reservoir shorelines. Recent tree plantings are being monitored to determine survival, growth, canopy closure, changes in floristic composition of associated herbaceous species, and mosquito populational changes.

INTRODUCTION

There are approximately 72,000 hectares of periodically dewatered or flooded shoreline habitat within the mainstream and tributary reservoirs of the Tennessee Valley Authority (TVA) system. This shoreline habitat is maintained by the fluctuating levels in the multipurpose reservoirs that are regulated for flood control, power production, navigation and recreation. Shoreline habitat, as defined here, is the zone between the expected minimum pool (winter drawdown level) and 0.6m above the normal maximum pool. It includes biologically productive communities such as timbered bottomlands, marshes, vegetated flats, and shallow overbanks, as well as areas that are unvegetated and extremely low in biological productivity. Many demands are made of shoreline habitat. It is valuable for private and industrial development; provides essential habitat for wildlife; serves a variety of recreational needs; and functions as an integral part of the reservoir ecosystem. It is also the source of problems such as siltation from unstable reservoir margins, mosquito production from existing breeding habitats, and aesthetically unpleasing expanses of barren dewatered flats and shoreline.

TVA has attempted to manage selected areas of its reservoir shorelines to alleviate specific problems on a demonstration and operational basis. Mosquito breeding habitat has been reduced by mechanical mowing of shoreline vegetation, tilling to bury mosquito ova, and planting water-tolerant tree species to alter vegetation. Shorelines have been stablized by seeding and planting of herbaceous and woody species, and waterfowl have been encouraged by seeding exposed dewatered areas with productive food plants. The challenge in managing these reservoir margins is to encourage biologically productive communities and utilize the unproductive areas while maintaining the reservoirs in the multipurpose mode for which they were created. Shoreline plantings of water-tolerant tree species have been studied as a potentially useful tool in managing the shoreline habitats for a diversity of benefits.

PAST STUDIES

Initially, tree plantings along TVA reservoir margins were established to determine if the shading influence of canopy closure would reduce populations of the anopheline mosquito (Anopheles quadrimaculatus Say) by reducing the herbaceous understory which is a favored breeding site of this insect. This anopheline mosquito was the primary malaria vector in the Tennessee Valley and the Southeast in the 1930's and inhabited the shallow reservoir shorelines in quiet protected areas where vegetation or flotage intersects the water surface. Silker (1948) summarized forestry studies of tree

[1]Paper presented at the National Symposium on Strategies of Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

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plantings conducted from 1935 to 1948 on TVA reservoir margins. These studies concentrated on the planting and initial establishment of water-tolerant trees planted in two zones: (1) the upper drawdown zone characterized by bottomland soils subject to intermittent inundation of 0.3 to 1.0m during the growing season, and (2) the reservoir surcharge zone composed of bottomland to upland soils subject to infrequent inundation during the dormant season. The water-tolerant species investigated include baldcypress [Taxodium distichum (L.) Richard], white cedar [Chamaecyparis thyoides (L.) BSP.], tupelo gum (Nyssa aquatica L.), sweetgum (Liquidambar styraciflua L.), water oak (Quercus nigra L.) sycamore (Platanus occidentalis L.), green ash [Fraxinus pennsylvanica var. subintegerrima (Vahl.) Fern.] and willow oak (Quercus phellos L.). Characteristics of growth, tolerance to flooding and site specificity for these species were presented based on studies of 445 hectares of 5 to 12 year-old plantings. Other studies on tolerance of woody species to various types and degrees of inundation include those by Hall and Smith (1955), Gill (1970), Broadfoot and Williston (1973) and Teskey and Hinckley (1977).

Smith et. al. (1969) documented the potential for tree plantings as a "biological, long range, economical mosquito control for certain types of reservoir shorelines." They found that in 32 year-old baldcypress (fig. 1) and tupelo gum plantations, permanent pool mosquito species such as the anopheline mosquitoes were reduced five-fold compared to adjacent open herbaceous habitats. They also found in studies conducted in McFarland Bottoms (Lauderdale Co., AL) that plant successional changes from an open grass-dominated habitat to a canopied, woodland habitat resulted in a corresponding change in the floodwater mosquito fauna. A mosquito complex (Aedes vexans Meigen, Psorophora columbiae Dyar and Knob, P. ciliata Fabricius and P. cyanescens Coquillett) which characteristically inhabits open grassland habitats and has a wide flight range was replaced by a less aggressive species complex (Aedes atlanticus Dyar and Knob P. ferox Humboldt and P. varipies Coquillett) which is associated with woodland habitats. The latter group remains within the woodland habitat and becomes annoying to man only when the habitat is invaded (Breeland and Pickard, 1967).

RECENT STUDIES

Although the initial studies were designed to evaluate the impact of tree plantations on mosquito breeding habitats, the plantings were also found to effectively eliminate expensive biennial rebrushing operations, produce diversified habitats for wildlife, produce a harvestable wood product, and provide aesthetically pleasing diversity to the shoreline landscape. Because of the potential for multipurpose use of tree plantings, additional baldcypress and certain other water-tolerant tree species have been established within the fluctuation zone of four main stream reservoirs and one tributary reservoir since 1968.

Figure 1.--A 32-year-old baldcypress planting.

Baldcypress plantings established at Mallard Creek [Tennessee River Mile (TRM) 294, Lawrence Co., AL] and Birdsong Creek (TRM 103, Benton Co., TN) in February 1970 and Duck River (TRM 110, Humphreys Co., TN) in February 1972 are being monitored to determine survival, growth, canopy closure and changes in floristic composition of the associated herbaceous vegetation. Mosquito population changes are also being monitored at the Mallard Creek and Birdsong Creek plantings along with environmental parameters such as temperature, humidity, solar radiation, pH, and dissolved oxygen. In addition to these baldcypress plantations, a planting of sycamore was established on the Hiwassee Reservoir near Murphy, NC in 1974 and is being monitored for survival, crown and diameter growth, and associated mosquito fauna. Unlike the recent baldcypress plantings, this sycamore plantation is located on a tributary storage reservoir that is subject to flooding at irregular intervals, hence, the duration and time of flooding is dependent on precipitation and subsequent runoff. Due to the relatively dry climatic conditions in the area since 1974, the planting has been inundated for only a six-week period in the past four years. Soil samples have been examined for mosquito ova, and larval sampling conducted when

the plantings were inundated. No impact on mosquito production has been demonstrated during the initial four years of study. However, tree survival has been greater than 90 percent and growth has been considered satisfactory (e.g., some seedlings planted in 1974 are over 5m in height and have a crown width of 3m).

The Mallard Creek plantings (two hectares) were established in the fluctuation zone between the normal maximum summer pool (169.5m m.s.l.) and the minimum winter drawdown level (167.6m m.s.l.). Three permanent 15.24m (50') transects were oriented parallel to contours at 169.5m m.s.l. (upper), 169.2m m.s.l. (middle), and 168.6m m.s.l. (lower). The line intercept method was used to determine percent cover of the planted and naturally occurring woody and herbaceous species (fig. 2). Height and width of the herbaceous species was recorded as well as survival, height, crown width, and diameter of the woody species. These methods were also employed at the Birdsong Creek and Duck River plantings.

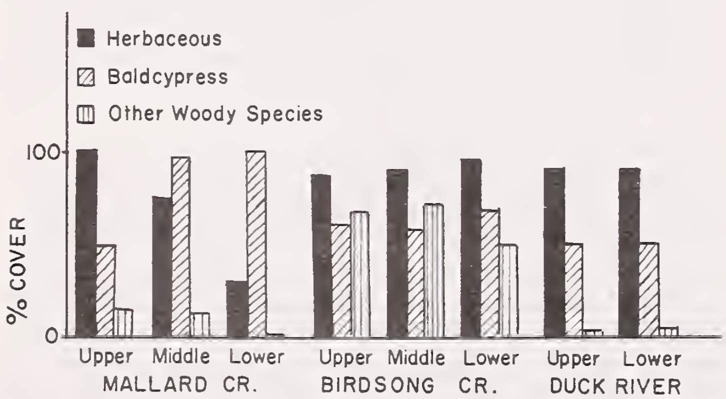

Figure 2.--Percent cover of woody and herbaceous vegetation for three baldcypress plantations.

Survival in the upper plot at Mallard Creek was only 86 percent and percent cover was only half that of the middle and lower plots. The upper plot being at the normal maximum summer pool level is infrequently inundated. This probably contributes to its lower growth rate through less favorable growing conditions for baldcypress and increased competition from less water-tolerant herbaceous and woody species. The baldcypress in the upper plot were over-topped and displaced by other competitive woody species, e.g., Cephalanthus occidentalis L., Rubus sp., Rosa palustris Marshall, and Lonicera japonica Thunberg. Over 40 species of herbaceous and woody plants were recorded from the upper plot which is exhibiting a successional trend from an open grass-sedge community to a woody complex of vines and shrubs. Early successional species such as sweetgum, red maple, (Acer rubrum L.) and persimmon (Diospyros virginiana L.) were also invading this infrequently flooded site. The plantings in the middle elevation plot had a woody cover value of 97 percent and are showing a reduction in herbaceous cover after eight years. Dominant herbaceous species at the time of planting were Aneilema keisak Hasskarl, Leersia oryzoides (L.). Swartz, and Juncus effusus L. Since 1970 A. keisak has become the dominant species in the plot along with lizard's tail (Saururus cernuus L.). The lower plot has essentially complete canopy closure, and the herbaceous cover has been reduced from 100 percent at the time of planting to 30 percent in 1978. The herbaceous species in this plot continue to be diminuative (<0.1m) growth forms, mostly annuals, that are commonly found on dewatered mud flats in late summer and fall [e.g., Eragrostis hypnoides (Lam.) BSP., Fimbristylis spp., Eleocharis spp., Cyperus spp., Ammnia coccinea Rottboell, and Rotala ramosior (L.) Koehne] (fig. 3). While there were slight changes in the dominant species over the eight-year period, such changes in dominant species typically occur even on undisturbed vegetated mud flats. (table 1)

Figure 3.--A one-year old baldcypress plantation following a late fall and winter drawdown of Wheeler Reservoir.

Table 1.--Dominant species in the herbaceous understory in three baldcypress plantations.

Species[1]	Mallard Creek Upper	Mallard Creek Middle	Mallard Creek Lower	Birdsong Creek Upper	Birdsong Creek Middle	Birdsong Creek Lower	Duck River Upper	Duck River Lower
Agalinis purpurea[2]	0[3]							
Ammania coccinea			0,1,2,7					
Aneilema keisak	0,1	0,1,2,7,8						
Apios americana				8				
Arthraxon hispidus	0							
Aster simplex	1			7,8	7,8	7,8	7,8	
Bidens frondosa				7,8			7	
Boltonia asteroides							7,8	
Brunnichia cirrhosa					7,8			
Campsis radicans				8				
Cyperus erythrorhizos			0,1,2					7
C. esculentus			8					
Diodia virginiana				1,2	2			
Eclipta alba							2	
Eleocharis acicularis			8			1,8		
E. obtusa			1			2,8		
Eragrostis glomerata							2	
E. hypnoides			0,1,2,7,8				2	2,7,8
Erigeron annuus	2							
Fimbristylis autumnalis			0,1			0,2,8		
F. vahlii			0,1					
Galium tinctorium		2						
Hemicarpha micrantha			8					
Juncus effusus	0,1,2	0,1,2						
Leersia oryzoides		0,1,2						
Lonicera japonica	7,8							
Mollugo verticillata								2
Panicum agrostoides				0,1,2,7,8	0,1,2,7,8	7		
Panicum sp	1,2							
Polygonum hydropiperoides					8			
Rhynchospora corniculata				1				
Rosa palustris	7,8							
Rubus sp	1,2,7,8							
Saururus cernuus		1,7,8						
Xanthium strumarium					0,1,7,8	0,1,2,7,8	2	2,7,8

[1]Data on the species composition of the herbaceous understory was not taken from 1973 to 1976.
[2]Nomenclature follows Radford et. al. (1968).
[3]0=1970; 1=1971; 2=1972, 7=1977; 8=1978

In the three plots (109.3m m.s.l., 108.8m m.s.l., and 108.5m m.s.l.) established at Birdsong Creek (fig. 4), survival of baldcypress was greater than 95 percent even though prolonged flooding (>two meters) for more than 30 days occurred when the plantation was three years old. The areal cover of baldcypress ranged from 57 to 68 percent in three plots, cover of other woody species ranged from 48 to 71 percent, and the herbaceous cover was greater than 87 percent in all plots. In the upper and middle plots, there was a slight change in floristic composition, but Panicum agrostoides Sprengel continued to be the dominant species. The lower plot was dominated by the mud flat assemblage listed previously.

In the six-year old Duck River Plantings (109.6m m.s.l., 108.7m m.s.l.), survival was 100 percent, baldcypress cover was 50 percent for both plots while herbaceous cover was about 90 percent. There was a change in species composition in the upper plot from the diminuative mud flat plants to a taller herbaceous complex of Aster simplex Willd., Boltonia asteroides (L.) L'Her., and Polygonum hydropiperoides Michaux. The lower plot remained colonized with the mud flat species.

Changes in mosquito population densities and species composition were monitored biweekly during the mosquito breeding season in Mallard Creek and Birdsong Creek using standard sampling

Figure 4.--A seven-year old baldcypress plantation within the annual fluctuation zone of Kentucky Reservoir.

techniques. Species collected include Anopheles quadrimaculatus, Anopheles punctipennis Say, Culex irraticus Dyar and Knob, and Culex territans Walker. Based on this sampling, the eight-year old plantings had not begun to exert a significant influence on the indigenous mosquito fauna.

SUMMARY AND CONCLUSIONS

Studies have been conducted since 1935 on shoreline plantings of water-tolerant tree species along TVA impoundments. Baldcypress has proven to be the most desirable water-tolerant tree species for planting in the fluctuation zone of reservoirs due to its rapid growth rate and ability to withstand prolonged flooding even in seedling stage. Planting of baldcypress seedlings allows establishment at contours where normal water level fluctuation would prevent ecesis from a natural seed source. Shoreline plantings provide a long range, economical biological control method for manipulating mosquito populations by hastening vegetative succession from open herbaceous communities to a woody, closed canopy community. This change in vegetation has been shown to reduce mosquito populations five-fold and to bring about a concommitant change in mosquito species composition to a less obnoxious and aggressive complex. Earlier studies indicated that these changes may occur within five to seven years, however, recent studies suggest that a longer period may be required. Recent plantings of baldcypress on an operational scale have been reduced by high populations of beaver (Castor canadensis). This factor, coupled with competition from herbaceous species in the upper portion of the fluctuation zone, appears to be the major limitation to successful plantings. Shoreline plantings also provide the potential for shoreline stabilization, increased habitat for wildlife, replacement of wetland habitat lost in reservoir construction, and an aesthetically pleasing diversification of shoreline landscape.

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Repairing Flood-Damaged Streams in the Pacific Northwest[1]

Ivan L. Lines, Jr., Jack R. Carlson, and Robert A. Corthell[2]

Abstract.--Soil Conservation Service approaches toward erosion control in stream corridors have changed to give more consideration to stream geomorphology and hydraulics and erosion processes. Greater reliance is placed on the use of vegetation, either singly or in combination with structural treatments. An effort is made to incorporate stabilization work into a stream corridor management framework meshing with fish, wildlife, agricultural, urban, and esthetic objectives.

INTRODUCTION

Most streams in western Oregon and Washington originate in steep, coniferous forested mountains. At lower elevations, gradients decline and the streams meander through broad valleys developed for agriculture or urban uses before flowing into the Pacific Ocean or Puget Sound. These streams, at least at lower elevations, have been heavily impacted by man's activities. East of the Cascade Mountains streams meander or cut through complex, relatively arid topography to the Columbia River. Flood plains are largely used for cropland, pasture and hayland, and for urban development. These streams have also been heavily impacted by man.

Streambank erosion, channel meandering, and flooding are natural processes. However, changes in watershed cover and runoff patterns and encroachment on the stream corridor by agriculture and urban development alter natural processes--frequently with catastrophic effects. Streambank erosion is a severe resource problem in Oregon and Washington. Man's activities in the stream corridor have in many cases depleted riparian vegetation, resulting in severe soil erosion, deterioration of fish and wildlife habitat, loss of esthetic appeal, and economic losses to landowners and taxpayers.

In Oregon, an estimated 3,800 miles of significantly eroding streambanks (primarily man-caused) are producing nearly 5 million cubic yards (3.8 million cubic meters) of sediment each year (Oregon State Soil and Water Commission 1972). The problem is at least as severe in Washington. Total sediment yield from streambanks in both states probably exceeds 10 million cubic yards (7.6 million cubic meters) per year.

For several years, the Soil Conservation Service (SCS) has provided assistance, primarily in rural areas, to stabilize streambanks in Oregon and Washington. Until recently, individual landowners, with occasional limited cost-sharing through the U.S. Department of Agriculture's Agricultural Conservation Progam, have installed most SCS-designed protective measures. Numerous landowners have installed measures without USDA technical or financial assistance. In addition, several thousand feet of streambank are treated each year by other government agencies such as the U.S. Army Corps of Engineers and county public works departments.

SCS approaches toward erosion control in stream corridors have changed. Greater emphasis is being placed on considerations of stream geomorphology, the importance of riparian zones to fish and wildlife, erosion processes, and stream hydraulics. This change of emphasis has been prompted by increasing SCS involvement in stream corridor management and a concurrent evolution of research dealing with the management of stream corridors.

SCS ASSISTANCE IN STREAM CORRIDORS

Soil Conservation Service work on emergency watershed protection in Oregon and Washington has increased dramatically in recent years.

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[1]Paper presented at the National Riparian Ecosystems Symposium, Callaway Gardens, Georgia, Dec. 11-13, 1978.

[2]State Biologist and Plant Materials Specialist, USDA-Soil Conservation Service, Spokane, Washington; and State Biologist, USDA-Soil Conservation Service, Portland, Oregon.

Severe flooding occurred in the winters of 1975-76 and 1977-78. Under authority of Section 216 of the Flood Control Act of 1950, SCS was authorized to treat flood damages (mainly to streambanks) in 5 and 4 counties in Oregon, and 12 and 13 counties in Washington in 1975 and 1977, respectively.

Total installation cost of emergency work in Oregon amounted to $3.2 million for 1975 floods, and $865,000 for 1977 floods. In Washington, installation totaled nearly $3 million for 1975 floods and will total nearly $4 million for 1977 floods. These figures do not include technical assistance provided by SCS or for other agencies such as the Corps of Engineers, State fish and game departments, or U.S. Fish and Wildlife Service. These agencies assist SCS in reviewing the proposed projects, conducting environmental assessments, and issuing necessary permits.

The SCS is also being asked with increasing frequency to assist individual landowners with "nonemergency"-type streambank protection. Most often, individual landowners undertake streambank protection projects of a lesser magnitude than those treated under Section 216.

The need for these smaller projects is usually prompted by the loss or imminent loss of dwellings or property. Most of these problems can be attributed to changes in watershed hydrology, stream hydraulics, or the character of streamside vegetation. Greater emphasis is being placed on providing technical assistance to landowners to treat potential streambank problems before they become problems. Treatment usually involves maintenance or reestablishment of streamside vegetation, structural revetments, and routine removal of toppled trees or accumulating organic debris.

EVOLUTION OF SCS POLICY

Before the 1970's, SCS assistance emphasized structural solutions, mainly rock riprap to control streambank erosion. Rock riprap has proven effective in preventing further bank erosion . However, it displaces valuable riparian vegetation, and it does not correct the original sources of the problem such as changes in watershed cover and runoff patterns, or man's encroachment within the stream corridor. Consequently, streambank erosion in adjacent reaches and flood-incurred damages continue to increase.

Prior to the 1970's the value of riparian zones was poorly understood or the loss of these zones was ignored because of the limited number of areas being impacted. However, as the amount of riparian vegetation replaced by riprap continued to increase, the value of riparian zones became more fully appreciated, and as nonstructural technology developed it became imperative to modify SCS treatment techniques. Klingeman (1976) indicates that in the past riparian land management "received much less attention than that given to lands away from streambanks...reflecting economic constraints, lack of knowledge of available techniques, or simply lack of concern". Now, SCS attempts not only to treat the immediate erosion problem, but also to develop enduring solutions consistent with other management objectives of the stream corridor.

Stream corridor management memoranda were recently issued by SCS state offices in Oregon and Washington. It is now SCS policy in these states to:

1. Maintain the bank-to-bank character of a stream and preserve meanders and gradient;
2. Establish vegetative and structural measures for erosion control, filtering sediment from adjacent eroded areas, and bank stabilization work. Structural measures shall not be installed without revegetating with indigenous or other acceptable riparian plants, unless approved by the state conservationist.
3. Implement stream corridor management that emphasizes control of livestock, protective fencing, removal of trees about to fall into the stream, appropriate fertilization of vegetation, and prompt repair of critical erosion spots.
4. Remove unstable organic debris with a minimum of disturbance to other features in the stream corridor.
5. Limit in-stream work whenever possible.
6. Prevent pollutants, such as septic tank effluent, sediment or livestock wastes, from entering the stream.
7. Comply with all state and federal laws and regulations.

This policy applies to all SCS assistance provided in stream corridors including emergency work under Section 216.

This approach is described by Klingeman (1976) as the "natural means of streambank stabilization" which he defines as bank shaping, vegetative management along streambanks, and riparian land management applied separately or in combination. Natural means of stabilization place minimum reliance on mechanical or structural techniques, and maximum reliance upon nature, aided by man.

EVOLUTION OF PHILOSOPHY

Structural revetments used for the spot-treatment of erosion usually have been successful and many people are reluctant to abandon the complete use of riprap in favor of alternatives of limited riprap and more vegetation. This reluctance has been reinforced by inexperience in stabilizing streambanks with vegetation. Unfortunately, there has been very little systematic testing of vegetation for streambank stabilization.

The use of heavy equipment in riparian zones can reduce biological values in these zones. For example, riparian vegetation frequently is removed to gain access to the site or to reslope the bank before rock or other structures are installed. A tree that has fallen into the stream provides rearing habitat for juvenile salmon or steelhead. But the same tree may obstruct streamflow, trap organic debris (a cause of eddying and further bank erosion), or hinder adequate preparation of the site for protection. A large, leaning, dead cottonwood tree (*Populus* spp.) provides habitat for numerous cavity nesting birds, but if it topples into the stream during the next high flow, it may direct the erosive energy of the stream toward the opposite bank. Proper management of a stream corridor projects the amount of fish and wildlife habitat necessary to sustain desired populations, and the amount of bank protection needed to sustain existing or planned land uses in the corridor.

While emergency streambank work restores the banks to predisaster conditions, it is difficult when performing this work to ignore the overriding cause of the problem. Accelerated erosion in stream systems often can be attributed to removal of vegetation by channelization, cultivation, overgrazing, burning or spraying, urban development, and/or upper watershed modification. While spot treatment of eroding banks will solve the immediate problem, it is inadequate to diminish future damages. Planning for the control of streambank erosion should consider the whole stream system. Physical characteristics of the stream should be described and guidelines for long-term treatment should be provided. Spot treatment, if needed, should be compatible with an overall stream corridor management plan.

In Washington and Oregon, the SCS is attempting to incorporate streambank stabilization work in stream corridor management plans for whole stream systems. Fish, wildlife, agriculture, urban, recreation, water quality, and esthetic objectives are considered. In Oregon the SCS, along with several individuals and agencies, recently participated in this type of planning on the South Santiam River (East Linn Soil and Water Conservation District 1975). River resources were inventoried, and an integrated management plan was developed. Emphasis is placed on the preservation, reestablishment, and management of streambank vegetation.

SCS has participated in an interagency effort spearheaded by the U.S. Army Corps of Engineers (Environmental Resources Section, Portland District) to develop coherent approaches to stream corridor management on the Willamette River. This group is engaged in several activities including (1) identification of reaches of the Willamette River which should be allowed to meander; (2) devising an early warning system to identify incipient bank erosion so that the need for major structural measures can be reduced; (3) and identification of alternative means of stabilizing banks that result in an improvement in fish and wildlife habitat.

In Washington, the SCS assisted several state and federal agencies prepare the "Grays Harbor Erosion Management Study" (1974). This study inventoried sources of erosion in one of Washington's major stream systems, the Chehalis River. A complement of structural and nonstructural means of erosion control were examined and a strategy for implementing a management plan was developed.

STREAMBANK PROTECTION SPECIFICATIONS

The SCS maintains specifications for all conservation practices involving SCS technical or financial assistance. These specifications provide guidance to SCS employees, landowners, and contractors on how to install the job so that a high-quality end-product will result.

The SCS national office is currently revising specifications for streambank protection to reduce structural work and to feature vegetative and other natural means. Available research (Klingeman and Bradley 1976; Palmer 1976; Parsons 1963) leads us to believe that revegetation can be used more than it has been in the past to stabilize banks and to improve fish and wildlife habitat and the esthetic appeal of these projects.

The following guidelines are being used in Oregon and Washington for planning 216 bank stabilization projects.

1. Revegetation to stabilize eroding banks receives first priority. Fast-growing riparian shrubs are planted at high densities to resist bank scour. Grasses and legumes control sheet and rill erosion. These vegetative linings or

buffer strips are 10 feet or wider to provide the resistance needed to control erosion.

2. On streams where velocities exceed 5 to 6 feet per second (1.5 to 1.8 meters per second), eroding banks are stabilized by structural means below the normal high-water level. Vegetation is used to stabilize the upper portion of the bank. Streambanks with toe scour are treated mechanically since vegetation will not grow below normal waterlines. Vegetation will not succeed without a stable toe. Where possible, jetties are preferred over riprap as they are more compatible with establishment of vegetation.

3. Fencing is required to protect vegetative treatments from grazing or other encroachment, and to maintain vegetative buffer strips on the top of the bank.

Willows (primarily *Salix lasiandra* and *S. exigua*) are the backbone of woody revegetation because they are easy to start from cuttings. In the spring following damage, cuttings are usually planted on 18-inch (45 cm) centers (45 to 50 thousand cuttings per hectare). To improve floral diversity, clump or understory plantings of other species are also recommended.

Figure 1.--A high-density planting of willow cuttings. Rock jetty upstream provides protection to planted area.

Woody plantings made with SCS technical assistance generally have been successful. Willows have been more successful than other plants. Thousands of cuttings have been successfully established in Wallowa, Umatilla, and Tillamook Counties in Oregon. Smaller maintained plantings of snowberry (*Symphoricarpos albus*), Oregongrape (*Mahonia aquifolium*), mountainash (*Sorbus sitchensis*), poplar, cotoneaster (*Cotoneaster* spp.) have been established in Grays Harbor, Pierce, Lewis, and Skagit Counties in Washington. Generally, high-density willow plantings are proving best for stabilization and are particularly compatible with jetties. Current costs for revegetation according to specifications generally are less than $1.50 per foot ($5.00 per linear meter) or $6,000 per acre ($15,000 per hectare). In comparison, the cost for a 20-foot (6-meter) high rock riprap can be as high as $18,000 per foot ($60.00 per linear meter) or $40,000 per acre ($100,000 per hectare).

SEARCH FOR IMPROVED PLANTS

The SCS plant materials center (PMC) in Corvallis, Oregon is currently evaluating 120 strains of native willow (primarily *Salix lasiandra*) under controlled conditions to find superior characteristics for streambank stabilization. Desirable traits include compact, dense growth form; pliable stems; freedom from disease; ease of establishment; and wide adaptation. The PMC in Pullman, Washington is evaluating 43 strains of snowberry and 22 strains of Oregongrape. Within 5 years, evaluations are expected for Columbia River willow (*Salix fluviatilis*), coyote willow (*Salix exigua*), red-osier dogwood (*Cornus stolonifera*), blue elderberry (*Sambucus caerulea*), vine maple (*Acer circinatum*), oceanspray (*Holodiscus discolor*), ninebark (*Physocarpus malvaceus* or *P. capitatus*), and sitka alder (*Alnus sinuata*). A selection of Douglas hawthorn (*Crataegus douglasii*) is being considered for commercial release for use in stream corridors.

TESTING OF OTHER TECHNIQUES

In many reaches, high stream velocities necessitate the use of rock to stabilize the bank. Because of fish and wildlife, recreation or esthetic objectives, it may also be necessary to attempt to reestablish a near-natural riparian plant community. In these situations we are attempting to use a mixture of rock and vegetation on the face of the bank. After the rock is in place, plant cuttings are inserted into soil in interstices in the rock. Plantings of this type, mainly using willows, have been highly successful. Within five to ten years the banks will assume the appearance of a natural riparian zone.

Because of high rates of precipitation in western Oregon and Washington, vegetation such

Figure 2.--A combination vegetative-structural treatment. Willow cuttings planted within rock riprap.

Figure 3.--Many areas of slightly eroding bank will recover naturally if afforded protection. Fencing is used to regulate use by livestock on streambank.

as willow, alder, snowberry, and blackberry (*Rubus* spp.) will rapidly invade many disturbed streambanks. In many cases streambank erosion was aggravated by the removal of these native plants by livestock grazing, cultivation, or other causes. The "trick" is to recognize potential erosion areas before a serious problem occurs. These reaches are then fenced to exclude livestock or a buffer strip at least 10 feet wide is established between the cultivated land and the edge of the streambank. Bare soil is seeded with an adapted grass-legume mixture to prevent sheet and rill erosion. Landowners also are encouraged to periodically inspect the condition of riparian vegetation. Trees that have fallen into the stream should be removed, preferrably with hand labor, before they collect large amounts of organic debris or direct the force of the stream toward the base of the tree or toward the opposite bank.

Another combination structural-vegetative practice that has proven successful involves the use of jetties. Built with rock or gabions, a series of jetties project into the stream from an eroding bank perpendicular to the direction of flow. Slack water is created downstream from each jetty against the bank. The bank in this area can then be stabilized with high density plantings of woody plant materials (see fig. 1). It should be noted that all areas receiving woody plantings are first planted to a grass-legume mixture to protect bare soil during the establishment of woody plants.

In eastern Oregon, several reaches of eroding streambanks have been stabilized using blankets of trees placed against the face of the bank. Because of their natural abundance, juniper (*Juniperus* spp.) trees are most often used. The butt ends of the trees are anchored to the bank, usually with cables, with the tops of the trees facing downstream, parallel to the bank. The trees reduce the velocity against the face of the bank which also results in some sediment deposition. Although this type of protection has a relatively short life, natural vegetation becomes established and can provide long-term protection if properly managed.

The key to vegetative streambank stabilization, with either naturally occurring vegetation or with plantings, is the management following treatment. In natural riparian zones, trees that have toppled into the water, or vegetation that is seriously reducing the capacity of the channel should be periodically removed. If performed on a regular basis, most material can be removed with hand labor, resulting in minimum disturbance to the bank or riparian plant communities. In planted areas it is frequently necessary to replant small areas where the original plantings have failed. It is also necessary to maintain a well-vegetated buffer strip on the top of the bank, free from cultivation or excess use by livestock. A well-vegetated buffer strip prevents surface runoff from adjacent land from causing sheet or rill erosion on the face of the bank. It also prevents vegetation on the face of the bank from being undermined

from behind during periods when the steamflow exceeds the capacity of the channel.

Studies are underway to monitor the performance of existing plantings and structural treatments. Evaluations will be made of how well the plants at various ages reduce the erosive velocity of stream against the face of the bank. Additional evaluations will be made to examine the effects of combination structural-vegetative treatments, plant spacing, mixtures of woody species, and combinations of herbaceous and woody species on bank stabilization.

CONCLUSIONS

The SCS in Washington and Oregon is being asked with increasing frequency to assist private landowners and other agencies with streambank erosion and stream corridor management problems. Structural techniques used in the past have been successful in spot treating streambank erosion. However, new philosophies and techniques are needed to consider the whole stream system, and to treat not only immediate erosion problems but to help alleviate future erosion and flooding problems. Management techniques employed must also consider other demands placed on the stream system such as esthetics, fish and wildlife habitat, and recreation opportunities. Hopefully, techniques will be perfected to help restore riparian vegetation. These approaches to stream corridor management can help reverse the deterioration of stream corridors in Oregon and Washington.

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Possible Strategies for Preservation of the San Pedro River Riparian Community[1]

Randy McNatt[2]

Abstract--Because of the scarcity of riparian habitat in Arizona and its obvious importance to fish and wildlife, the U.S. Fish and Wildlife Service is investigating methods to preserve remaining riparian areas along the San Pedro River, southeast Arizona. Possible strategies include acquisition under the Unique Ecosystems Program, enactment of local ordinances, and state-wide legislation.

Riparian areas in the arid Southwest have undergone significant physical and biological changes since the early 1800's. Nowhere is this resource deterioration more obvious than in the Colorado River and tributaries such as the Gila, where many former riparian communities are now absent or severely reduced in size.

The San Pedro River, a major tributary to the Gila, enters the United States from Sonora, Mexico, approximately 100 km east of Nogales, Arizona (fig. 1). The river channel then runs NNW for approximately 200 km to its confluence with the Gila River near Winkelman, Arizona. Headwaters of the river are located 40 km south of the International Boundary, near Cananea, Mexico. Total area of the San Pedro basin is 11,621 km^2, of which 1802 km^2 occur in Sonora. Elevation of the river channel is 1303 m above mean sea level at the International Boundary, and drops to an elevation of 585 m at its confluence with the Gila River, an average gradient of 4 m/km (Roeske and Werrell, 1973). The largest tributary to the San Pedro is Aravaipa Creek, which drains an area of 1530 km and enters the San Pedro mainstream 19 km upstream from Winkelman (fig. 1).

San Pedro valley sediments, bounded by several desert mountain ranges composed of low-permeability, crystalline and consolidated sedimentary rocks, consist of well-bedded semi-consolidated to nonconsolidated valley-fill material overlain by floodplain alluvium. The valley-fill upstream from Benson ranges from 90 m - 644 m thick, but has generally been eroded away further downstream (Reichhardt et al., 1978).

Floodplain alluvium, consisting of gravel, sand, and silt, along the channels and floodplains of the San Pedro mainstream and its tributaries ranges in thickness from 12 to 43 m. This alluvium is very porous and is capable of producing water flows in excess of 2000 gallons per minute (7.57 cubic meters per minute). Ground water in the alluvium is under strong artesian pressure in the vicinity of Palominas - Hereford, St. David-Benson, and Mammoth. Further downstream, ground water occurs at increasing depths beneath the surface (Roeske & Werrell, 1973).

Because of high sediment porosity, ground water withdrawn from the alluvium is rapidly replaced by infiltration from periods of high surface runoff. During the past 25 years, net change in ground water level has been negligible except in the Sierra Vista-Fort Huachuca area due to domestic-industrial uses. The relatively constant ground water level may be due in part to replacement of riparian vegetation by irrigated agricultural land (Roeske and Werrell, 1973).

Lack of substantial lowering of ground water since the early 1950's, however, does not mean that the flow regime of the San Pedro has not been radically altered. Diversions, headwater impoundments, depletion of underground aquifiers, and a possible regional tendency toward increasing aridity have reduced surface flow in the mainstream to that of an intermittent stream,

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[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Pine Mountain, Georgia, December 11-13, 1978.

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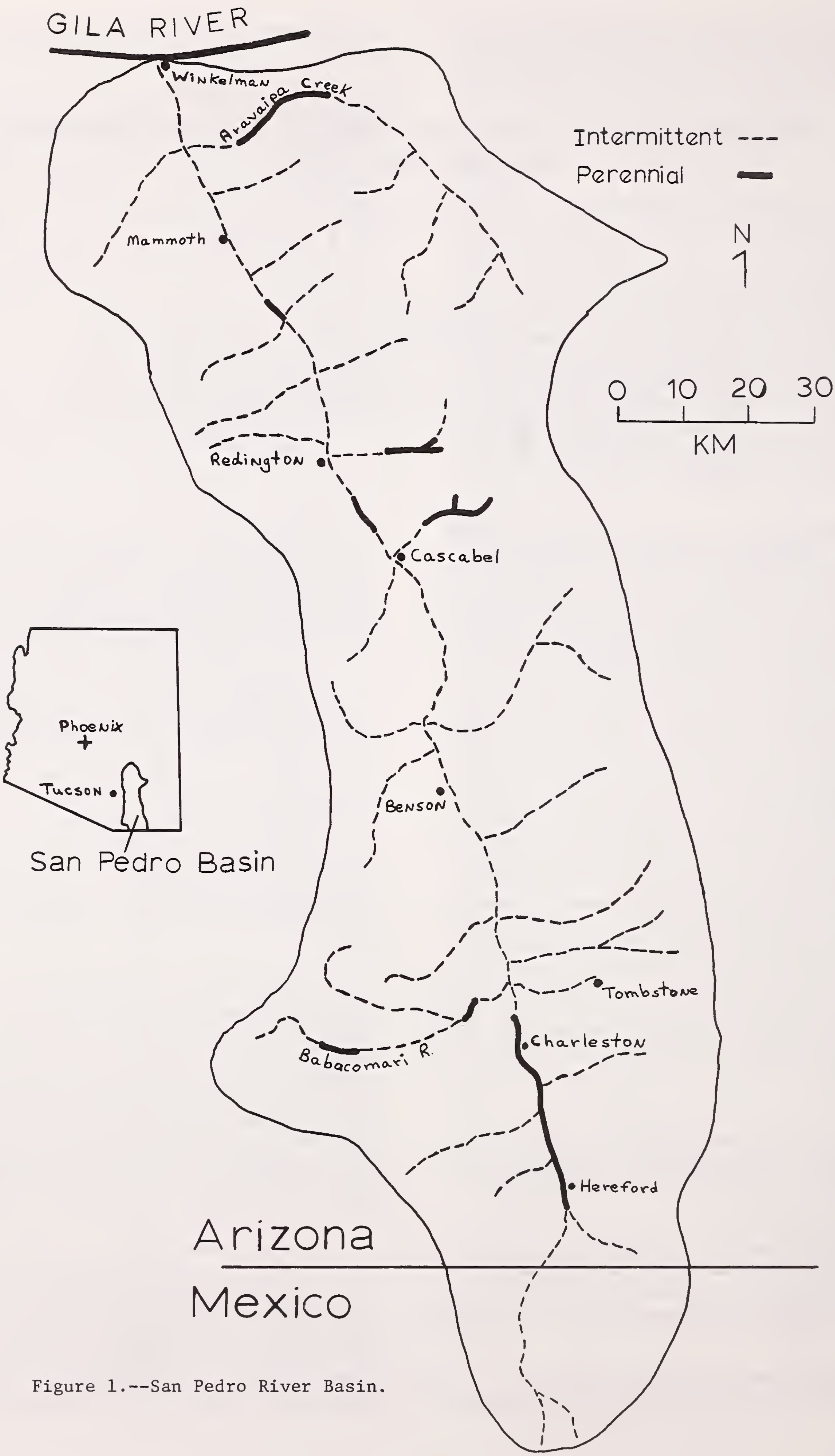

Figure 1.--San Pedro River Basin.

with permanent water present in three main sections which comprise only 50 km of the total river length of ca 250 km (fig. 1). That the San Pedro historically contained consistently high surface flows is documented by occurrence of Colorado River squawfish, *Ptychocheilus lucius*, (Miller, 1955), a species confined to swift, big-river habitats in excess of one meter deep (Minckley, 1973). The San Pedro drainage historically supported at least 12 native fish species. Aravaipa Creek, the largest tributary, presently contains 7 of 12 fishes reported, and is the only portion of the entire drainage that supports a relatively secure native fish fauna. Of these 7 species, 5 have not been reported elsewhere in the basin since at least 1963; the remaining 5 species likewise were eliminated prior to 1963. Further reduction of the already-depleted native ichthyofauna occurred in February 1978, when pollutants from copper mining operations on the San Pedro headwaters in Sonora, Mexico, apparently destroyed all fishes in the upper portion of the mainstream. Reestablishment of fishes in this section must occur from tributaries such as the Babacomari River where small populations of native species occur.

According to Brown et al. (1977), only a few southwestern drainages such as the Rio Magdalena in Sonora, Mexico, and the San Pedro in Arizona, presently contain any extensive linear riparian forest development. Such forests were once extensive, but have decreased dramatically in area during the past century due to diversions and/or elimination of streamflows. Davis (1973) mentions prior accounts of the extent of riparian forests along the Santa Cruz, Gila, and Colorado Rivers before 1900. Such forests are difficult to imagine when one views the present remnants. Remaining riparian plant communities are continually subjected to upstream impoundments, channel cutting (fig. 2), channelization, irrigation diversions, groundwater pumping, and, in many areas, increased water salinity. In addition, overgrazing by cattle has negatively affected remaining forests, especially cottonwoods, which reproduce primarily from seed rather than sprouts (Horton et al., 1960).

A recent study by Reichhardt et al. (1978) compared various land-use practices along the San Pedro River from 1935-1978. Somewhat surprisingly, conclusions were that riparian areas composed of cottonwood, mesquite, salt cedar, and willow had increased since 1935, as had agricultural and cultural-industrial areas (Table 1). These increases occurred simultaneously with a decrease in areas such as marsh lands, mesquite-scrub, river channel, and streambed thickets of annual and/or immature riparian species. However, these authors also concluded that, although mesquite and salt cedar areas appear to have increased significantly since the

Figure 2.--Bank erosion on San Pedro River south of Winkelman, Arizona.

early 1900's, cottonwood and willow associations require essentially perennial streamflow and consequently are declining. Events which are implicated in the increase of mesquite along the San Pedro and other southeastern Arizona drainages (Hastings and Turner, 1965) are: overgrazing by cattle in the late 19th century; subsequent runoff and flooding; and climatic drought and lowering of the water table.

Table 1.--Acreages of land use and vegetation types of the San Pedro River, 1935-1978 (from Reichhardt et al, 1978). Numbers in parenthesis indicate percentage of total acres.

Type	1935	1966	1978
Dense Riparian[1]	17,300 (22)	30,400 (39)	35,200 (45)
Agricultural	8,900 (11)	14,600 (19)	22,300 (28)
Cultural-Industrial	950 (1)	1,600 (12)	7,000 (9)
Other[2]	51,650 (66)	32,300 (40)	14,300 (18)
Total Area	78,800	78,800	78,800

[1]Cottonwood, mesquite, salt cedar, and willow.
[2]Marsh, mesquite-scrub, river channel, and streambed thickets of annual and/or immature riparian species.

Riparian areas along the river and its tributaries are continually threatened with destruction from numerous types of development. Loss or alteration of this habitat type from floodplain clearing and conversion to other land uses is taking place at an alarming rate. Agriculture, industry, recreation, and urbanization are all contributing factors to the alteration or destruction of riparian habitat.

Although significant riparian areas presently occur along the San Pedro, clearing of mesquite and cottonwood lands, primarily for agricultural use, is continuous, especially in the Mammouth-San Manuel and Winkelman-Dudleyville areas. Studies have indicated the high wildlife

potential of similar communities along the Verde and Lower Colorado Rivers in Arizona (Carothers and Johnson, 1970; Anderson and Ohmart, 1976, 1977). Wauer (1977) found that many bird species regularly used the Rio Grande riparian corridor as a migration and emigration route. Similar utilization of the San Pedro riparian zone would be expected. Important raptors such as Mississippi kites, black hawks, gray hawks, and zone-tailed hawks are presently using mature cottonwood stands in the San Pedro basin as nesting sites.

A recent occurrence south of Mammoth, Arizona, illustrated what is generally happening to fish and wildlife habitat along much of the San Pedro. A new locality for the Gila topminnow, *Poeciliopsis occidentalis occidentalis*, was identified in July 1978, in the outflow of an artesian well. At that time, clearing of mesquite immediately adjacent to the site was underway. By September, the well piping had been partially capped and dense mesquite around the well was removed by bulldozer (fig. 3). Much of the outflow area had become silted in and few fish could be observed. By early October, the well had been completely capped and connected to an irrigation system in the adjacent cleared area, resulting in complete drying of the former habitat and extirpation of the topminnow population. This incident is particularly significant because the well outflow was the only known locality in the entire San Pedro basin where *Poeciliopsis* was still present, and was one of only seven naturally-occurring populations presently known in the U. S. Thus, in a matter of three months, an important endangered species population was both discovered and extirpated.

Figure 3.--Artesian well locality of Gila topminnow, *Poeciliopsis o. occidentalis*, south of Mammoth, Arizona, September 1978.

Because of the scarcity of riparian habitat in Arizona (only 0.003%) of total vegetative cover and its obvious importance to fish and wildlife, preservation studies of the remaining riparian areas along the San Pedro River are actively being pursued by the U. S. Fish and Wildlife Service. These investigations fall primarily into two categories. First, portions of the San Pedro mainstream are being considered by the Division of Refuges and Wildlife for possible acquisition under the Unique and Nationally Significant Ecosystems Program, including easements as well as land purchases. This program is operated under authority of the Land and Water Conservation Fund Act of 1965 to purchase land and water defined as either "nationally significant wildlife ecosystems" or "unique wildlife ecosystems." These two types of ecosystems are defined as:

1) Nationally significant wildlife ecosystems: areas which have wildlife habitat values which go beyond local values in that they provide substantial benefits to many people over a wide geographical area.

2) Unique wildlife ecosystems: wildlife habitats that are significantly different from other habitats in the region and support natural wildlife communities.

Wildlife diversity and value to endangered, threatened, or other special recognition wildlife are primary considerations in identifying areas under this program. Such areas are managed as units of the National Wildlife Refuge System. Recreational, educational, and scientific uses will be encouraged and managed where appropriate.

Portions of the San Pedro River are being considered under the Unique Ecosystem Program because riparian woodlands are undoubtedly the habitat type of greatest concern in Arizona from both the standpoint of animal diversity and threat of destruction. Riparian habitat along the San Pedro provides nesting, migratory or wintering habitat for at least 20 raptor species and a total of approximately 210 species of birds. A study by Hoffmeister and Goodpaster (1954) recorded 78 species of mammals in the grassland corridor between the riparian woodlands and adjacent mountains. This represents the second-highest mammalian diversity recorded in the world, making the area one of national significance. Also, the San Pedro provides vital habitat to many species which interchange between Mexico and the United States.

The second thrust of preservation efforts on the San Pedro River has been initiated by the Riparian Habitat Analysis Group, U. S. Fish and

Wildlife Service. This group, based in Albuquerque, was organized to facilitate resource analysis, information development, and preservation efforts relative to riparian habitats. Investigations to date have centered on the feasibility of local ordinances, perhaps similar to those recently initiated in Shasta, Napa, and Santa Cruz counties, California.

The Napa County ordinance, enacted February 1974, seeks to prevent and/or minimize losses from flooding by regulating activities within "certain watercourses" and "protecting the riparian cover within specified distances thereof." The County Board of Supervisors recognized riparian vegetation as a "valuable natural resource" and, in the legislation, mentioned such benefits as increased wildlife diversity, enhanced fish habitat, maintenance of lower water temperatures and consequent retardation of algal blooms, bank stabilization, reduced siltation, and enhancement of aesthetic values. Non-permitted activities include planting or removing any vegetation within a watercourse. Violations of the ordinance are punishable by a fine not to exceed $500.00, or by imprisonment not to exceed 6 months in the county jail, or by both. However, the Conservation, Development, and Planning Commission of Napa County has the authority to issue permits for activities which would be in violation of the ordinance. No permit may be issued if the Commission determines that the proposed work will "substantially impair the water conveyance capacity of the watercourse, or destroy a significant amount of riparian cover." Interestingly, the permit procedure does not apply to public agencies and their contractors.

The Santa Cruz legislation, enacted June 1977, is entitled "Riparian Corridor Protection." Purpose of the ordinance is:

> "To preserve, protect, and restore riparian corridors for: protection of wildlife habitat; protection of water quality; protection of aquatic habitat; protection of open-space, cultural, historical, archaeological and paleontological, and aesthetic values; transportation and storage of floodwaters; prevention of erosion; and general promotion of the public health, safety, and welfare in Santa Cruz County."

Some pre-existing agricultural and non-agricultural land uses within Santa Cruz County are exempted from the ordinance, as are activities permitted under a valid timber harvest permit. In addition, the County Zoning Administrator has the authority to issue exception permits under certain conditions.

In Shasta County, riparian protection is contained in a section of the county flood plain zoning ordinance which reads: "No natural riparian vegetation shall be removed from any portion of this District adjacent to the Sacramento River or any stream named as a designated floodway by the State Reclamation Board except by a federal or state agency, Shasta County, or Shasta County Water Agency." As in Napa and Santa Cruz counties some exceptions to the ordinance are provided for.

Current efforts of the Riparian Habitat Analysis Group have centered on the San Pedro riparian areas in Pinal County, Arizona, and include: delineation of land ownership in riparian areas; documentation of vegetational changes and of fish and wildlife populations; investigation of local support for preserving riparian areas; and, investigation of local and regional political institutions, especially water conservation and/or irrigation districts.

Recently, environmental considerations have received emphasis in Arizona from Governor Bruce Babbitt with the formation of the Governor's Commission on Arizona Environment. Preservation of riparian habitats is one of the areas of prime concern to Governor Babbitt and the Commission. As a result, Robert D. Curtis, Chief of the Wildlife Planning and Development Division, Arizona Game and Fish Department, has lead efforts to introduce legislation to provide for "protection of water courses and riparian environment" in Arizona. The proposed legislation is currently being refined and amended and will be introduced for consideration by the State legislature in early 1979. Wording of the proposed act is as follows (in part):

> "No person shall engage in any project or activity which will alter a watercourse or riparian environment without first applying to and receiving a permit therefore from the department."

At present, "watercourse" is defined as "any lake, river, creek, stream, wash, arroyo, channel, or other body of water having banks and bed through which waters flow or have flowed at least periodically;" "department" is defined as the State Land Department.

Since the Riparian Team has directed its efforts on the San Pedro River to include support of the statewide preservation efforts, contacts have continued with county officials in Pinal County, including the Director of County Zoning and Planning, and County Commissioners, to inform them of the proposed legislation and to encourage their support of the act.

One group which supported the California riparian legislation was the beekeepers within

the State, since many apiaries are dependent, especially at certain times of the year, on riparian vegetation as a nectar source. The Arizona Beekeepers Association was contacted to inform them of the proposed legislation, and a member of the Riparian Team addressed the annual statewide meeting in Phoenix. The presentation emphasized benefits of preserving riparian habitats, with emphasis on the apiary industry, and encouraged the support of members of the Beekeepers Association, both as a group and individually.

SUMMARY

In summary, because of its uniqueness and its importance to fish and wildlife, the San Pedro River riparian community has been recognized as an area to be preserved. Efforts toward this end are continuing and are apparently gaining momentum, as evidenced by recent progress in establishing state-wide protection for riparian habitats in Arizona.

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Protecting Riparian Ecosystems from Competing Urban Pressures The Swan Creek Experience[1]

Richard H. Ginn and James H. Burbank[2]

Protection of riparian ecosystems requires considerations that go beyond enviornmental issues. Often, wetlands in or adjacent to urbanizing communities are under extreme pressure to accomodate intensive development. Comprehensive regional planning provides the basis for multidisciplinary resource assessments which offer a framework for resolving wetland use conflicts. TVA's planning effort at the Swan Creek Wildlife Management Area offers insight into how varied interests can be combined to reach balanced resource management decisions.

INTRODUCTION

As a regional planning and resource development agency, the Tennessee Valley Authority (TVA) is charged with carrying out a broad multipurpose mission. In addition to its specific responsibilities for reducing flooding, improving navigation on the Tennessee River, and producing and distributing electric power, TVA was given broad regional planning responsibilities. Section 22 of the TVA Act of 1933 gives the President the option "to make such surveys of and general plans for said Tennessee basin and adjoining territory as may be useful to the Congress and to the several States in guiding and controlling the extent, sequence, and nature of development in order to help foster orderly and proper physical, economic, and social development of the Valley." Section 23 of the Act further authorizes the President to recommend to Congress legislation deemed proper to bring about "the proper use of marginal lands. . . and the economic and social well-being of the people living in said (Tennessee) river basin."

A major portion of these marginal or retained public lands represents the riparian ecosystem characteristic of eastern mid-America. They contain a diverse mix of rich agricultural and hardwood forest communities, and, because of their relatively flat aspect and nearness to navigable water, are used to meet a variety of land uses--recreation, industry, wildlife management, scenic protection, and flood storage.

These sometimes competing uses have resulted in extensive modifications to the riparian zones on TVA reservoirs over the years. In meeting other uses, wildlife values generally were reduced, but certain key wildlife riparian areas were recognized by TVA as needing greater protection from competing uses.

TVA's Wheeler Reservoir, located between river miles 275 and 349 on the Tennessee River, is in the heart of the riparian wetlands in north Alabama. The Swan Creek Wildlife Management Area, located on Wheeler Reservoir and operated by Alabama Department of Conservation and Natural Resources, is a key wildlife unit. The steps which were needed to assure the protection of this wetland area involved the carrying out of a land use planning process designed to reduce land use tensions in the Swan Creek area, and thereby maintain the integrity of the wetlands contained therein.

This paper describes the multipurpose regional planning process which was used to respond to this need. The significance of this successful application is that the process holds potential for further use in other TVA reservoir land use problem areas. Perhaps it also is a workable approach for solving other kinds of land use problems in similar areas which exhibit wetland conservation opportunities.

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[1] Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Dec. 11 - 13, 1978, Pine Mountain, Georgia.

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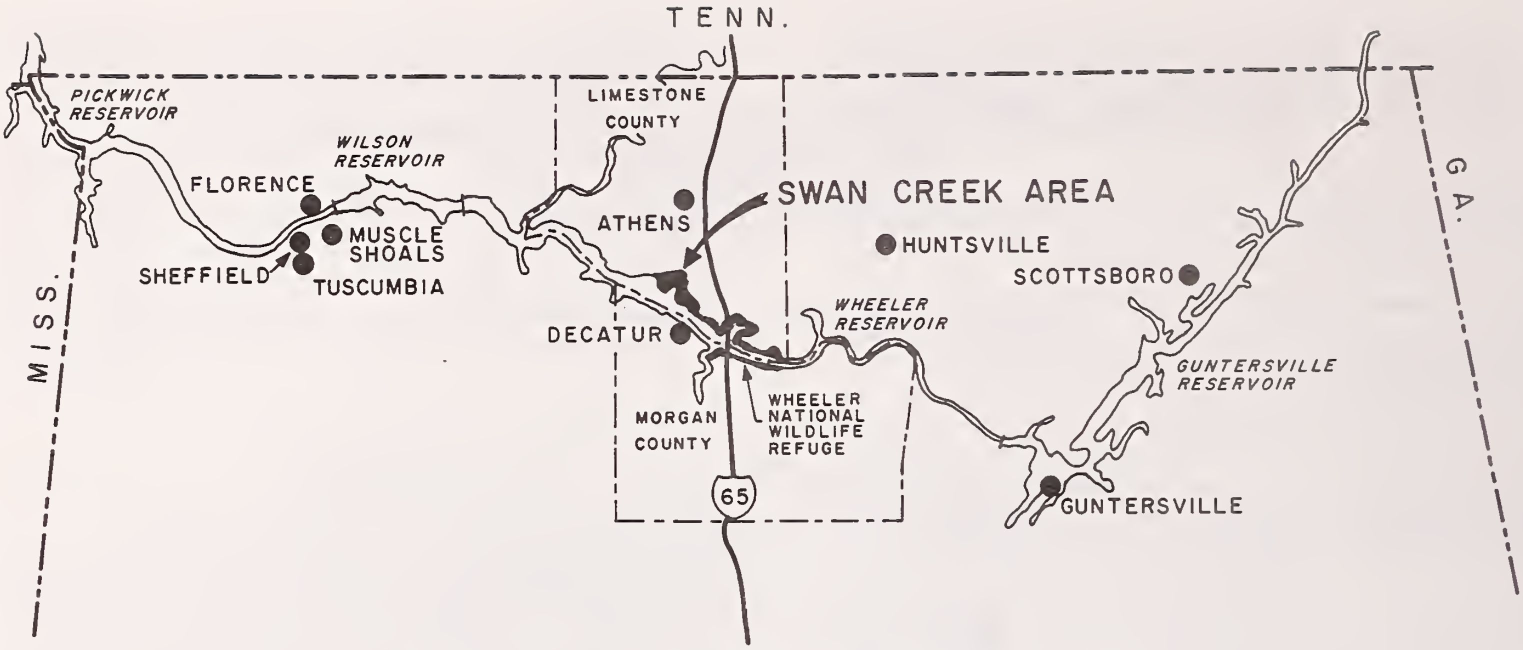

Figure 1.--Swan Creek area near Decatur, Alabama.

REGIONAL SETTING AND DEVELOPMENTAL CONFLICTS IN THE SWAN CREEK AREA

North Alabama Regional Setting

The general nature of the developmental problems in north Alabama is demonstrated by the general population trends in the area (U.S. Department of Commerce). In 1940, just after TVA completed the construction of Wheeler, Pickwick, and Guntersville Reservoirs, the combined total population of the 13 north Alabama counties was 509,000 people. By 1950 this total had increased by 23,000 people, and by 1960 another 45,000 had been added. In the next 10 years, 113,000 people were added to the region with the result that by 1970 the total population of the region was approximately 690,000. Population projections for the region suggest a continuation of these trends through the year 2000.

Equally important to the growth in population have been the shifts with the population itself. Since 1940, the farm population has declined from about 50 percent of the total population to less than 10 percent. This means, of course, an overwhelming concentration of nonfarm people within the region, and these in turn are located primarily in and around the major cities of the region. Thus, north Alabama (as the Nation), becomes more and more committed to an urban way of life, and the old division between urban and rural lifestyles tends to disappear.

Swan Creek Area

The Swan Creek area is situated in a strategic location between the urbanizing communities of Athens and Decatur, Alabama (see figure 1). This, together with the area's proximity to the navigable waters of the Tennessee River (Wheeler Reservoir), means that various reservoir-oriented land use needs must be accommodated in the near future in a manner which is sensitive to wetlands preservation. These uses include expanded residential, industrial, and navigational uses as well as intensified wildlife management and recreation activities.

SWAN CREEK WILDLIFE MANAGEMENT AREA

Uses and Benefits

The Swan Creek Wildlife Management Area (figure 2) is located on TVA's Wheeler Reservoir north of Decatur, Alabama, and is bounded on the east by Wheeler National Wildlife Refuge. Swan Creek is situated uniquely to complement the migratory waterfowl development program on Wheeler. Only about one-sixth the size of the Federal refuge's 34,500 acres, it nevertheless furnishes the premier public waterfowl hunting opportunity in the State. The keys to its success are: (1) the hundreds of acres of shallow water and mudflats, areas exposed by the fall drawdown of the Wheeler Reservoir, and (2) the Harris Dewatering Unit covering approximately 1,500 acres, a system which affords the diked water control capability for intensive, maximized waterfowl-wetland wildlife management.

A wetland evaluation was conducted in order to describe the character of this riparian wildlife habitat (table 1) using the FWS national wetland classification system (Cowardin et al. 1977). Forested wetland covers 1,200 acres, emergent wetland is found on 1,500 acres, vegetated mudflats comprise 3,500 acres, and its shoreline margin includes 30 miles of wetland scrub-shrub edge.

Figure 2.--Swan Creek Wildlife Management Area, Wheeler Reservoir, Limestone County, Alabama.

When Alabama began the development of the 6,000-acre Swan Creek Management Area in 1949, all activities were directed toward waterfowl management. Fields were enlarged by removal of hedge rows, and the 1,500-acre dewatered slough was cleared of stumps and tree regrowth to facilitate row-crop farming. Benefits to wildlife other than migratory waterfowl were quickly recognized. In response to this, and to the increasing number of people enjoying upland wildlife, songbirds, or merely having an interest in nature, a broadened wildlife management program has evolved. The 3,045 acres of land are managed for wildlife protection,

Table 1. Wetland Classification For Swan Creek Wildlife Management Area (Cowardin et al. 1977)

System	Subsystem	Class	Subclass	Modifier
Area 3,500 acres				
Lacustrine	Littoral	Flats	Mud Vegetated	Seasonally Flooded and Artificially Flooded
Area 30 shoreline miles				
Palustrine	--	Emergent Wetland and Scrub/ Shrub	Persistent and Nonpersistent	Seasonally Flooded and Artificially Flooded
Area 1,200 acres				
Palustrine	--	Forested Wetland	Broad-leaved Deciduous	Saturated Artificially Flooded
Area 1,500 acres				
Lacustrine	Littoral	Emergent Wetland	Nonpersistent	Artificially Flooded Diked

water and soil conservation, and for local agriculture as it complements the wildlife development program.

Swan Creek is opened for hunting of all resident game and fur-bearing animals, migrant waterfowl and doves during the hunting season which extends from mid-September through February, about 160 days per year. It furnishes approximately 12,000 man-days of hunting recreation annually.

In addition to hunting and fishing on approximately 3,000 acres of Wheeler Reservoir waters within the area's boundary, boating, nature photography, birding, sightseeing, and nature study are popular on Swan Creek. Camping is also permitted. These activities add another 12,000 man-days of use at Swan Creek. With proper development, these uses should enjoy a twofold to threefold increase within the next decade.

Indicative of the long-range migratory waterfowl objectives held by Alabama is the recently executed three-way agreement among that agency, the Fish and Wildlife Service, and TVA to share in the normal costs to operate and maintain the dewatering unit, handle routine levee maintenance costs, and for capital improvements such as dewatering pump equipment. This action plus the considerable State effort to manage Swan Creek Wildlife Management Area ($109,000 per year) supports TVA's migratory waterfowl development objectives. These efforts are also recognized by the Fish and Wildlife Service as being an important adjunct to their work at Wheeler National Wildlife Refuge.

Currently, the hunting effort alone at Swan Creek is valued at over $382,000 per year (Horvath 1974, for economic values of recreational trips), and is expected to increase to over $590,000 annually in future years if needed improvements are completed. Fishing recreation, now valued at $1,436,800, should rise to $2,000,000 per year by 1990. In addition to hunting and fishing, other related outdoor activities are presently valued at $208,320 and should double or even triple in years to come.

Existing Urban/Industrial Development Activities

The Decatur side of the river (left bank), extending about nine miles downstream from the Wheeler National Wildlife Refuge, has a unique combination of flood-free land and rail, river, and highway transportation facilities all in close proximity. The existing industrial firms located on the Decatur waterfront (figure 3) have invested more than $650 million and employ over 7,200 people. They are visible proof that water transportation is an important part of the region's economic development. Further development of navigation facilities is needed to continue supporting this growing complex.

In addition to the urban expansion need evident on the left bank of Wheeler Reservoir, the right bank, i.e., Limestone County, is beginning to undergo change. In the last 10 years, several urban/industrial developments have occurred altering the character of the shoreline area and backlands, and establishing a precedent for future development. These include the construction of TVA's Browns Ferry

Figure 3.--Decatur, Alabama, waterfront, looking downstream, south shore, Wheeler Reservoir.

Figure 4.--Relationship between Decatur Transit Company and Swan Creek Wildlife Management Area, Wheeler Reservoir, Alabama

Nuclear Plant, General Motors Saginaw Steering Gear Plant, the Tennessee Valley State Vocational Technical School, and the completion of I-65 in Limestone and Morgan Counties.

Until recently the area immediately adjacent to the Swan Creek Wildlife Management Area was rural and open in nature. With the advent of the more urban uses occurring in close proximity to the wildlife area, improved highway transportation, and the provision of urban water distribution and wastewater collection services in this area of south Limestone County, the stage is set for an even more rapid evolution from rural to urban character.

The Program

These mounting development pressures, together with the State of Alabama's desire to enhance the existing wildlife management activities, led to a critical and involved developmental conflict situation. The conflict involved the wildlife interests seeking long-term tenure on TVA reservoir lands (at this time the State only had a 90-day revokable license from TVA to use this land), private and public industrial interests seeking increased navigation facilities, TVA power program interest in potential generating sites and transmission line access in the area, and other local interests seeking recreation and residential land uses.

This conflict had intensified during the last few years as a result of two specific requests for developments in the Swan Creek area. One request was for longer tenure from TVA for wildlife management purposes by the State of Alabama, Department of Conservation and Natural Resources at Swan Creek. The State saw a need for long-term commitments from TVA to allow an improved wildlife management program. This included a $265,000 capital improvements program at the Swan Creek Management Area to be carried out over the next 10 years. The other request was made by Decatur Transit Company, a privately operated barging enterprise, which provides needed fleeting, switching, and related navigation functions to the Decatur waterfront area industries. Decatur Transit has limited space on the left bank of Wheeler Reservoir to carry out its functions in an efficient manner (see figure 4). The company's request was for approval of needed additional mooring facilities immediately south of the Swan Creek Management Area along the Tennessee River navigation channel (see figure 4). The capital investment cost associated with this proposal is estimated to be $250,000.

This then became the dilemma which TVA addressed. Regional planning provided an opportunity to evaluate needs and compare alternatives to meeting these needs both on and off the reservoir land, as well as furnishing a meaningful mechanism whereby interested parties could mutually discuss their needs and arrive at satisfactory solutions to potential conflicts.

MULTIPURPOSE REGIONAL PLANNING - A TOOL FOR LAND USE CONFLICT RESOLUTION IN THE SWAN CREEK AREA

Traditionally, major land use conflicts on TVA reservoirs have largely been resolved through a "big stick" approach. This approach was basically one in which the most powerful interest group was successful in seeing its needs met. Here "powerful" has several connotations. Typically, it might be thought of as political support; however, it can also be a measure of public support through effective presentation of what a proposal may mean in traditional economic terms, i.e., jobs and income. In the case of less intense uses, such as wildlife and recreation, public support might be based on visitation or enhancing the quality of life for Valley residents. Under such an approach there is no guarantee that all issues will or can be equally weighed with balanced decisions resulting.

These problems can be viewed as part of the national recognition of the need for a development balancing mechanism, a recognition that has included passage of major Federal legislation including the National Environmental Policy Act of 1969 (NEPA). With NEPA came the requirement for environmental impact statements (EIS) and a different way of looking at effects of Federal actions--including major TVA land transactions. (All TVA land use actions do not require EIS's, but environmental evaluations are made to document the magnitude of potential impacts.)

These developments coupled with other coordination requirements suggest that multipurpose regional planning is a mechanism for a more comprehensive evaluation of actions which have potentially significant impacts. Further, it is seen as an alternative approach for solving conflicts involving multiple interests. Such regional planning is viewed as an exercise in intergovernmental relations which begins with efforts to get people with functional program interests to talk to one another about common concerns, issues, and conflicts. This means that industrial developers, recreationists, urban planners, wildlife managers, navigation specialists, and others must communicate with each other and share information about area objectives. As expected, there were many times when the lack of trust between interest groups was very intense. There were even cries of blackmail in the North Alabama Waterfowl Association monthly newsletter when TVA actions suggested compromise and land use coexistence rather than complete support of wildlife interests at the expense of other interests.

Even with these difficulties, regional planning has proceeded. Through a process which involved TVA staff working with counterparts in other agencies and the private sector, the principal interests in the Swan Creek area were asked to identify their essential needs for the use of reservoir lands and their secondary or minor needs. This amounted to an assessment of the shoreline and related backland in terms of lands which programs affected "must have" and lands they "could do without" in the pursuit of their program interests. These assessments resulted in the identification of some areas where compromise was possible.

For example, the primary wildlife interests were seeking longer tenure on TVA property in the Swan Creek area which would give them assurances that their existing land base would not be eroded by other uses. In years past, both the Swan Creek area and portions of the Wheeler National Wildlife Refuge had been subject to uncompromising encroachments and land losses due to power transmission and highway crossings. These losses have been largely responsible for the wildlife interests taking negative views on more recent economic development proposals. Given assurances that the integrity of the existing Swan Creek Management Area and its related riparian habitat would be maintained, wildlife interests indicated that access easements traversing the area could be accommodated adjacent to existing corridors or in new corridors which could be located in nonsensitive parts of the management area.

The assessment of industrial developmental potential revealed that use for manufacturing purposes of much of the land presently in the wildlife management area is highly unlikely due to significant engineering and environmental problems associated with navigation channel dredging and other development in wetlands. However, areas immediately behind and adjacent to the management area have very high potential for future industrial use. Further, reevaluation of four alternative navigation sites (mooring cells) on the south side of Wheeler Reservoir revealed that even though these could be used, they would involve significant cost increases (due to dredging), and they would not meet efficient barging, switching, and other water transit standards.

Additional assessments also were made of potential power generating plant sites. Due to the proximity of the existing Browns Ferry Nuclear Plant, together with the probable impact which additional generating capacity would have on the existing Swan Creek Wildlife Management Area, it was

concluded that the Swan Creek area should not be considered a future generating plant location.

All of these assessments were made by TVA staff in cooperation with affected outside agencies, groups, and individuals. Their collaboration is viewed as extremely important in the process of land use decision-making and conflict resolution. Further, through the A-95 process, most interest groups eventually will have an opportunity to formally review and comment on land development proposals. Prior agreement on an area land use concept is considered essential to successful A-95 coordination.

Development Concept

As the process continued, areas for potential compromise became clearer. The result was the fitting together of a puzzle which revealed that most essential needs could be accommodated with some relinquishing by all parties of their secondary needs. Figure 5 portrays the development concept which emerged from the process (Ginn and Wright 1978). Full-sized multicolored prints are available from the authors.

The development pattern expressed recognizes the importance of the Swan Creek Management Area in the State's wildlife program in north Alabama. Setting aside TVA land at Swan Creek for long-term wildlife resource development, as reflected in this development concept, posed no serious conflicts to other land uses provided flexibility was maintained for a variety of access corridors through the management area. These will be needed to meet future development requirements of the private lands beyond the north side of Wheeler Reservoir. Backland development as noted on the concept will probably be mixed uses, i.e., manufacturing, residential, agricultural, and open space usage. While the exact extent and nature of these uses is unknown at this time, selected corridors across nonsensitive management areas will be required in the future. The types of access envisioned include water supply, wastewater discharge, railroad industrial lead tracks, and commodity pipelines. The locations of these are shown on figure 5.

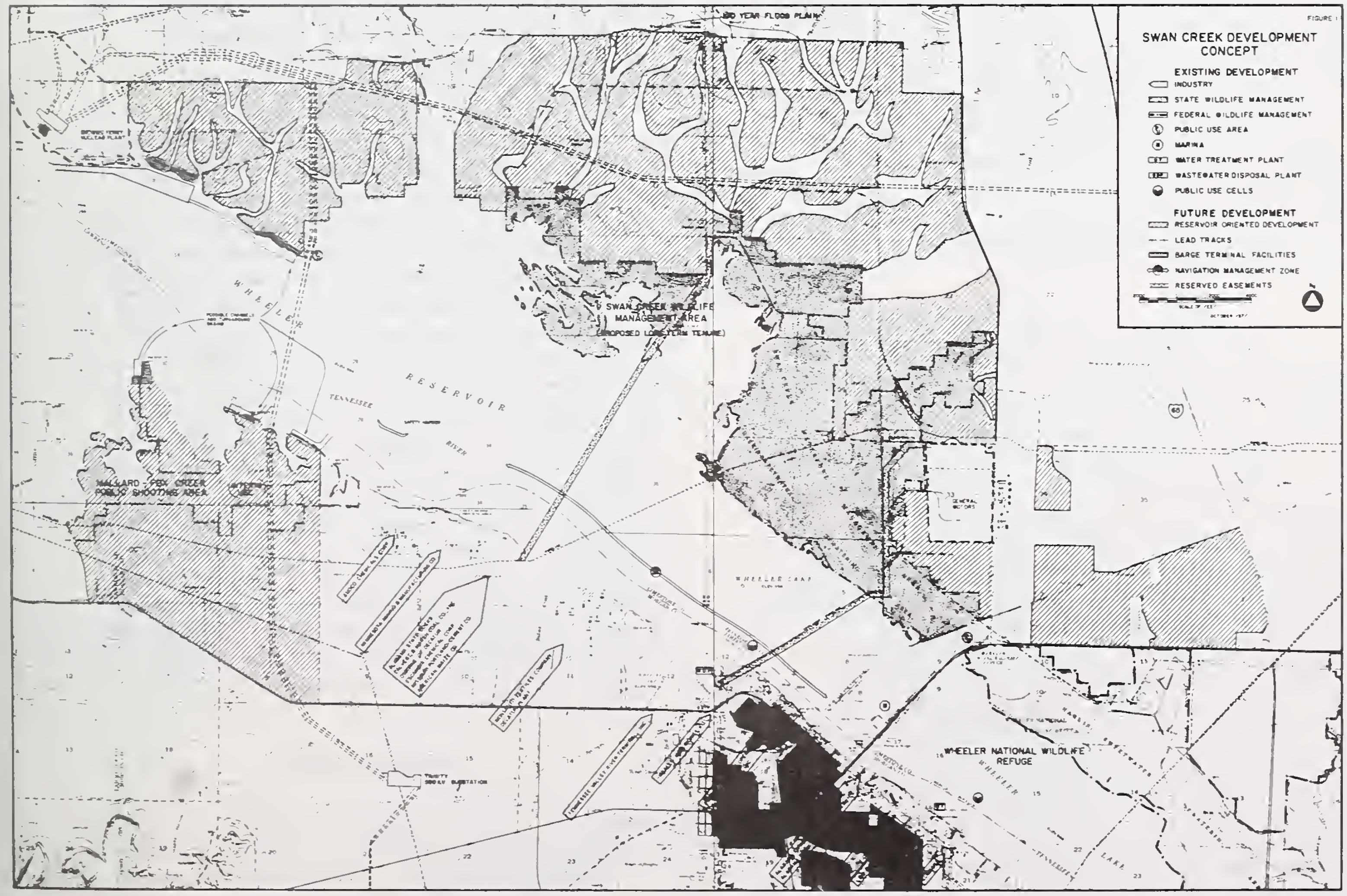

Figure 5.--Swan Creek area development concept, Limestone and Morgan Counties, Alabama.

Barge channels to accommodate potential industrial development on the north side of Wheeler Reservoir, either dredged or nondredged, would be prohibited within the Swan Creek Management Area. The concept plan recognizes that these needs could be met downstream, on both the left and right banks, where compatibility problems are not expected to occur.

The development concept recognizes that very few waterfront sites are left undeveloped along the Decatur waterfront (left bank). The grant of longer tenure and related permanent improvements on the Swan Creek Management Area will further reduce dependence on the Mallard-Fox Creek Public Shooting Area across the river at mile 297 (figure 5). Based on this fact and as part of the basis for justifying longer tenure of the Swan Creek area, the concept plan shows the Mallard-Fox Creek area continuing as an interim use wildlife area. However, the plan reflects the State-TVA understanding which anticipates that while ultimately this area will shift to navigation-oriented industrial use, there could still be some residual wildlife use opportunities there.

Internal improvements within existing manufacturing plants on the left bank are expected to continue to result in increased productivity. These, together with the potential for new manufacturing plant construction on the right bank backlands, are expected to reinforce the need for expanding navigation improvements. Such improvements will need to include increased mooring and fleeting capacity for left bank industries and the navigation companies that serve these industries.

Accommodation of these on the north bank of the navigation channel will be necessary in the future. Thus, the concept proposes a navigation management zone extending 500 feet north of the main river navigation channel between river miles 300.47 and 304.35. This will allow adequate room for mooring cells and an appropriate buffer between the wildlife management area and commercial navigation activities. Use envisioned in the navigation management zone includes mooring and fleeting facilities, public use mooring cells, pipeline terminal platforms near the proposed corridor easements, and other navigation-related facilities which may be required in the near future. Further, the concept specifically proposes that, as a part of the long-term easement for the Swan Creek Management Area, the Alabama Game and Fish Division recognizes the presence of the navigation management zone.

As a part of the negotiations that led to agreement on the land use concept, wildlife management interests have acknowledged that, through proper planning, the needs outlined in the concept can be met without undue impact on the waterfowl program.

IMPLEMENTATION AND FUTURE ACTIONS IN THE SWAN CREEK AREA

General agreement on the ideas expressed in the Swan Creek area development concept provided the basis for negotiating proposed conflict resolutions. Since affected TVA program interests had been involved in identifying and choosing between available alternatives, positive agency staff support for the proposed concept was assured. External review of the development concept occurred as a part of the overall land use proposal for granting the State of Alabama a 30-year wildlife recreation easement on the wildlife management area. Through A-95 review, the proposal was reviewed and commented on by the interested State and regional clearinghouse agencies. At the State level this included those State departments concerned with wildlife management, transportation, State planning and industrial development, and historical preservation. At the regional and local levels, affected planning agencies and governmental units participated. All the comments were positive.

On May 17, 1978, following successful review, the TVA Board approved a 30-year wildlife recreation easement and letter permit on the Swan Creek properties. On August 29, 1978, the State Department of Conservation and Natural Resources signed the legal instruments designed to change the tenure and reduce land use tensions in the area. Since the development concept recognizes the proposed location of mooring cells on the right bank near the wildlife management area, Decatur Transit Company is in the process of resubmitting its original request for navigation improvements. Once these related but independent actions are completed, construction will be initiated on over one-half million dollars worth of planned wildlife and navigation improvements, and coordinated, rather than conflicting land uses will have been the result.

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Public Involvement in Riparian Habitat Protection A California Case History[1]

Anne Sands[2]

Abstract.--This paper was written to stimulate public involvement in riparian ecosystem protection and management in California by (1) summarizing the history, values, and current status of riparian forests; (2) reviewing government policies and actions affecting riparian areas; and (3) describing five successful strategies being used to preserve riparian habitats.

INTRODUCTION

Summary

Public involvement in riparian habitat protection is based on a recognition of the unique values offered by the forest associations found along California's major rivers and their tributaries. This recognition, in turn, depends on public education. Many Californians have never seen a riparian forest. Those who have, may only glimpse some willows and cottonwoods through an automobile window as their car speeds over a bridge. These people have not taken the time to sit quietly in the cool breeze on a river bank and watch a spectacular wood duck swim serenely by or listen for the raucous call of a yellow billed cuckoo. To be fully appreciated, riparian forests must be heard and felt as well as seen.

One important reason for a lack of public contact with these habitats is that nearly ninety percent of the prime riparian forest lands are in private ownership. In some cases this fact has protected the forests, but in many cases it has brought about their destruction.

Protection strategies for these forests must be based on a solid understanding of their history, current status, and values to society. The protagonist must be thoroughly familiar with government policies and actions regarding riparian areas, as well as innovative when suggesting ways to protect these fragile ecosystems.

This paper begins with brief discussions of the geographic setting of California's riparian forests, their values, geologic history, recent history and current status. Following these introductory statements is a summary of federal, state and local policies and actions affecting riparian habitats, and strategies for citizen action. Some of the problems encountered by citizens trying to effect changes in management policies are discussed, and a challenge is made to those in government to encourage more public involvement toward the ultimate goal of statewide watershed management.

Geographic Setting

The great central valley of California is a vast alluvial plain averaging 50 miles in width and extending from Redding to Bakersfield, a distance of over 400 miles. There is no other flat area of this size west of the Rocky Mountains. Rainfall varies from seven inches in the south to 40 inches in the north, but most of the valley receives an average of 10 inches per year and remains relatively dry from May to November (Bakker 1971 and USACE 1975).

The Sacramento River, after joining the Pit and McCloud rivers near the base of Mt. Shasta, receives waters from the American, Feather and Yuba rivers as it flows south. The San Joaquin River flows west, is deflected by the Coast Ranges, and subsequently flows north, being fed by the Merced, Tuolumne, Stanislaus, Mokelumne, and Cosumnes rivers. Where the Sacramento and San Joaquin meet, they form a great delta which covers over one thousand square

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[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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miles and discharges almost one half of California's runoff water through the Suisun Bay and into the San Francisco Bay (DAPC 1976). This central valley drainage system supports the largest remaining stands of riparian forests in the state.

South of the Tehachapi Mountains and east of the Sierra lie two separate basins: the Mojave Desert and the southern extent of the Great Basin Desert. Four hydrologic systems function in this part of the state: the Mojave, Colorado, and Owens rivers and a series of palm oases. The north coast, central coast, south coast and northeastern sections of California also support their own unique riparian forest associations.

Description

Riparian forests are highly productive habitats found along the major rivers and tributaries in California where there are abundant water supplies, high nutrients, and coarse textured, well aerated, well drained soils (Roberts, et al. 1977). They represent cool retreats for wildlife and man during the long dry summer, and provide abundant food and nesting sites for a great variety of animals. They have been described by many as gallery forests, reminiscent of tropical jungles, especially in summer when vines of wild grape and Clematis hang in profusion. The trees are often so crowded and the undergrowth of poison oak and blackberry vines so tangled that it is nearly impossible to pass through.

These are the only forests in California dominated by broad leaved, mesophytic, winter-deciduous trees (Conard 1977). The large number of genera in common with the deciduous forests of the Eastern United States, including Acer (maple), Populus (cottonwood), Platanus (sycamore), Fraxinus (ash), Quercus (oak), Alnus (alder), and Juglans (walnut), show the close floristic affinities of these regions (Robichaux 1977). Species lists of the dominant woody plants - trees, shrubs, and vines - found in the riparian forests of each division of the state have been published (Roberts, et al. 1977).

The riparian forest and its fluvial system are dynamic and interdependent. As a river overflows its banks, natural levees are built from the deposited sediments. Additionally, overbank flows supply water to adjacent floodplain lands which store excess runoff water and allow groundwater recharge. As a river erodes its channel on the outside of a bend and deposits on the inside, the meander bend moves laterally and down the valley while maintaining constant overall channel shape and size. These two processes, overbank flow/deposition and lateral migration, are the most significant forces in formation of a floodplain. The riparian forests respond by establishing successional stages of growth on new sand and gravel bars, beginning with Salix hindsiana (sandbar willow) and other low plant cover. As gravel bar communities become more distant from the shifting river, they begin to stabilize and are further colonized by tree saplings. Gradually, a new riparian forest, dominated by Populus fremontii (Fremont's cottonwood), is established.

This natural balance is easily upset by human interference in the floodplain. To restore the riparian forest/fluvial system balance, two facts must be recognized by communities which compete with the riverine environment: (1) flooding is a natural process rather than a natural hazard, and (2) if we are to maintain the integrity of the riverine system, we must consider the channel and floodplain as complementary (Keller 1977).

Values of Riparian Habitats

The most important scientific basis for protection of these habitats is their unique diversity of wildlife. More kinds of birds breed in riverine forests than in any other habitat type in California, and over 100 avian species are known to visit these forests for food and cover (Brumley 1976, Gaines 1977). In the Sacramento Valley alone, thirty nine species of mammals, nineteen species of reptiles and amphibians, twenty seven species of fish, seventeen species of butterflies and numerous other invertebrates depend on these forests for survival (Alley et al. 1977, Roberts et al. 1977, Shapiro 1974, Stone 1976). Fifteen rare and endangered species, including the yellow billed cuckoo, bald eagle, California hibiscus and giant garter snake, are found in California's riparian habitats.

The importance of riparian vegetation to fish has been documented (Hynes 1970, Mann 1975). Fish use submerged tree roots along the banks of streams and rivers for cover. Terrestrial insects dropping from overhanging vegetation are an important source of food. Other allochthonous materials such as leaves and twigs which enter the water serve as substrates for bacterial and fungal action. The resulting detritus is a vitamin-rich food supply for certain aquatic insects which are indispensable in the diets of many fish species. In addition, trees provide shade for temperature regulation, a critical factor for aquatic life.

Well known recreational values of riparian areas include fishing, bird watching, nature photography, hunting and canoeing. Other social benefits are derived in the forms of open space, outdoor education, natural beauty and scientific study. Even in a narrow band of riparian

vegetation, one can experience peace, solitude, and relief from the pressures of urban life. Riparian forests provide additional health and economic benefits by acting as natural filters which remove pollutants from air and maintain or improve water quality.

As California's population grows and more demands are made on existing timber and fuel resources, riparian forests are being considered as harvestable crops. Suggestions have been made to plant selected native riparian trees along levees, berms and urban rivers to supply future timber and fuel needs while providing cover for wildlife and open space for human enjoyment.

Geologic History

Evidence from fossil floras suggests that lowland riparian forests have had a nearly continuous history in California during the last twenty million years. Because of major climatic changes that occurred during the late Tertiary, the modern forests are less diverse than their ancestral communities. Nevertheless, at least fourteen fossil tree species have counterparts in today's riparian forests. These survivors include *Acer negundo* (box elder), *Alnus rhombifolia* (white alder), *Cornus californica* (California dogwood), *Fraxinus latifolia* (Oregon ash), *Juglans hindsii* (black walnut), *Platanus racemosa* (California sycamore), *Populus fremontii* (Fremont's cottonwood), *Quercus lobata* (valley oak), *Salix lasiandra* (black willow), *Salix lasiolepis* (arroyo willow), *Salix laevigata* (red willow), *Salix goodingii* (willow), *Salix hindsiana* (sandbar willow) and *Toxicodendron diversiloba* (poison oak). A detailed discussion of the geologic history of riparian forests in California is presented by Robichaux (1977).

Recent History

Prior to 1814, the riparian woodlands of California were seldom visited by Europeans. Although settlements had been established in southern and northern California and along the coast, the central valleys with their extensive marshes and nearly impenetrable riverine forests were left to the native Americans and the abundant wildlife. Among the first outsiders to explore the Sacramento Valley were fur trappers from the Hudson's Bay Company. These men were followed by a rapid succession of explorers including the Spaniard Luis Arguello, Jedediah Smith, Sir Edward Belcher and Lieutenant George H. Derby. Diaries, field notes, maps and topographic surveys from their expeditions are the only records we have of the once vast riparian jungles which flanked the bottomland rivers of California. Unfortunately, there were few botanists along to record details of species diversity. However, quotations from journals help to recreate the general appearance of riparian growth (Belcher 1843).

Most of the historical accounts do not indicate the depth of the forests, but references are found suggesting belts of trees averaging from two to four or more miles in width on both sides of the rivers; even tributaries had forests two or three miles wide (Thompson 1961).

The gold rush of the 1850's caused many significant environmental impacts on riverine ecosystems of the central valley. California's population soared. Rivers continued to be the major transportation corridors and floodplain camps became cities while people turned from gold mining to farming. Riparian trees were used for building materials and fuel, especially on the steam powered paddle wheelers which cruised the Sacramento-San Joaquin Delta carrying food, supplies and passengers. Marshes were drained, levees cleared, and the rich alluvial soils were prepared for planting orchards and crops. The same conditions which created lush riparian forests-ample water and nutrients-eventually led to their destruction, as fruit trees replaced sycamores and settlements replaced wildlife habitats.

Current Status

As agriculture expanded and urban centers grew in California's central valleys, more pressure was exerted on the remaining wetlands and riparian forests. It is estimated that there were still about 775,000 acres of riparian forests along the Sacramento River in the 1850's. By 1952, however, this figure had dropped to 27,000, and 1972 calculations showed there were less than 18,000 acres of riparian habitat remaining on the Sacramento River (McGill 1975). Most of this loss occurred on high terrace lands. Other California rivers suffered similar fates.

Conversion of riparian lands to agriculture was facilitated by the construction of dams, reservoirs, by-passes and canals. These allowed flows to be controlled and promised to reduce flooding while providing irrigation water when needed. With this protection in mind, farmers removed the trees and shrubs, which had helped to stabilize banks, and planted more orchards. The rivers continued to meander and undercut their banks, as they had always done. Seepage through levees became serious in some areas, and drainage, too, became a problem. When rivers meandered and levees failed, landowners and county supervisors appealed to the state and federal governments for a solution.

Construction of federal flood control and bank protection projects in California began in the 1920's and continues today. Projects

were installed by the United States Army Corps of Engineers and maintained by local districts monitored by the State of California. During typical project construction, all vegetation was removed from the river banks, then 2:1 slopes were cut and covered with rock rip rap. In addition, maintenance manuals generally required clearing of all volunteer vegetation from levees in order to facilitate inspection for leaks. The results were aesthetically shocking rock slopes which provided very little habitat for the displaced riparian forest wildlife. As bank protection projects increased in number, it became apparent that there were no long range plans for the control of bank erosion and sediment deposition. Projects were authorized without requiring adequate site-specific environmental impact studies, and mitigation was not included as part of a project.

Clearing of riparian forests for bank protection and levee work in the Sacramento-San Joaquin Delta in the early 1960's finally triggered public reactions of dismay and outrage. Management of riparian habitats became a controversial issue statewide. It was realized that numerous local, regional, state and federal agencies were involved, and that an understanding of government policies and actions at all levels had to be developed before public involvement could bring about desired changes.

GOVERNMENT POLICIES AND ACTIONS AFFECTING RIPARIAN HABITAT PROTECTION

Federal Policies

Several laws and policies, differing in origin and intent, may be effective in preserving California's riparian habitat. The National Wild and Scenic Rivers Act of 1968 (Public Law 90-542:82 Stat. 906, et seq) can be applied to entire watersheds to ensure better management of water quality and land use. The broad definition of "river" in Section 15(a) has not yet been applied to its full extent in California. In this law, "river" is defined as "a flowing body of water or estuary or a section, portion, or tributary thereof, including rivers, streams, creeks, runs, kills, rills, and small lakes."

The federal Fish and Wildlife Coordination Act (16 U.S.C.A. Sec. 661 et seq) requires federal agencies to accommodate the conservation of wildlife resources insofar as it is consistent with the primary purposes of their projects.

The federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500, Sec. 208; 86 Stat. 816 et seq) are intended to "restore and maintain the biological integrity of the Nation's waters." This legislation is being implemented through federal, state, and regional water quality plans. Section 208, which specifically requires water pollution controls for both point and non-point sources including soil erosion from poorly managed watersheds, has great significance for riparian vegetation protection. One example of a federal 208 program application is the Streamside Management Zone concept which is being applied in California on both state and private forest lands (USFS and EPA 1978).

The Federal Code includes an interesting provision for revegetation in flood control areas: "Where practicable, measures shall be taken to retard bank erosion by planting of willows or other suitable growth on areas riverward of levees." This statement, from Title 33, Navigation and Navigable Waters, Chapter II. Part 208. 10b(1), would allow considerable rehabilitation of riparian areas where levee work has been done.

Executive Order 11988, May 24, 1977, Flood Plain Management (42 FR 26951), requires that federal agencies shall "take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains." Responsibility for implementing this order rests with the Council on Environmental Quality, the Water Resources Council and the Federal Insurance Administration of Housing and Urban Development. An important tool of these federal agencies is the National Flood Insurance Program established in 1968. This program enables property owners to buy flood insurance at a reasonable cost. In return for protection, communities must carry out flood plain management measures (U.S. Water Resources Council 1978).

Executive Order 11990, May 24, 1977, Protection of Wetlands (42 FR 26961), calls for "action to minimize the destruction, loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands." This order took effect on all federal projects begun after October 1, 1977, and specifically includes "swamps, marshes, bogs and similar areas such as sloughs, potholes, wet meadows, river overflows, mudflats and natural ponds."

The executive branch continues to show concern over expensive water development projects and their environmental impacts. Several memoranda from the President to his cabinet have emphasized non-structural alternatives in flood control, as well as accomodation of instream flow needs below proposed dams or other water project facilities. Provision of funding for mitigation of fish and wildlife damages "concurrently and proportionately with construction

funding" is one of the criteria listed for new projects, as well as for continued authorization of existing projects (Carter 1978). Public works bill HR 13059, attacked as being inflationary and wasteful, was vetoed by the President on October 5, 1978; the House sustained his veto. These actions seem to indicate a new conservative attitude toward initiation of expensive federal water development projects.

Probably the most far reaching federal law affecting riparian habitat is the National Environmental Policy Act (NEPA) of 1969 which requires Environmental Impact Statements (EIS) for all federal projects (42 U.S.C. Sec. 4321 et seq). Currently the State of California is trying to use NEPA to require a site specific EIS for each new section of a bank protection project.

Federal Actions

Riparian habitats in California are affected by several federal agencies. The Bureau of Reclamation (Department of the Interior) designs projects which provide irrigation, municipal, and industrial water, hydroelectric power, and flood control. Shasta Dam, completed on the Sacramento River in 1943, is part of the largest Bureau undertaking in California: the Central Valley Project. The Army Corps of Engineers (Department of the Army) builds multipurpose water projects, aids in developing local water supplies, and assists in flood control, flood plain management, levee and channel maintenance, and improvement of navigable waterways. Technical service to local Resource Conservation Districts regarding water development, flood prevention, irrigation, drainage, fish and wildlife enhancement, and recreation is provided by the Soil Conservation Service (Department of Agriculture). Basic data on the source, quantity, quality, and distribution of surface and ground water are provided by the Geological Survey (Department of the Interior). This agency also conducts studies of climate, topography, vegetation, soils and watersheds.

Projects of these four federal entities, all having important impacts on riparian habitat management, are subject to review and coordination by the Environmental Protection Agency to assure compliance with such regulations as the Federal Water Pollution Control Act. The Fish and Wildlife Service (Department of the Interior) also has environmental monitoring responsibilities, authorized under the Fish and Wildlife Coordination Act, and is concerned with establishing adequate mitigation for terrestrial and aquatic riparian habitat losses due to water project construction. In California, the Service has become extensively involved with the Sacramento River Bank Protection Project, which is under the jurisdiction of the Corps of Engineers and the State of California. Vegetation removal and increased turbidity resulting from project construction are considered as major impacts of water projects on the fish and wildlife resources of California's riverine ecosystems.

State Policies

State policies and codes which influence protection of riparian vegetation include the Governor's Environmental Goals and Policy of 1972, the California State Park System Goals and Policy of 1977, the Water Code, the Public Resources Code, the Fish and Game Code and the Government Code. Several specific sections within the Resources Code have direct impacts on riparian habitat management. The most general of these is Section 21002, the California Environmental Quality Act of 1970 (CEQA), which established state policy for environmental protection, maintenance, and enhancement and created the Environmental Impact Report (EIR) process. The State Wild and Scenic Rivers Act of 1972 (Sec. 5093.50 et seq) is similar to the National Act discussed under Federal Policy. The Department of Fish and Game prepares management plans for each waterway being considered.

The Forest Practice Act of 1973 (Sec. 4526) is applicable to riparian trees in some parts of the state, but it has not been interpreted to include riparian forests as commercial timber, in spite of the fact that these trees are chipped and sold as wood fiber. Two 1978 acts were established with the intent of restoring California's forest lands and increasing employment in the forest industry: the Forest Improvement Act and the Urban Forestry Act. These laws could provide unique opportunities to establish "crops" of riparian trees along some watercourses and to plant urban forests along rivers such as the Sacramento.

The Surface Mining and Reclamation Act of 1975 (Sec. 2710 et seq) applies directly to sand and gravel mining in watercourses, and has language providing for fish and wildlife protection and revegetation of mined areas. In addition to water quality and stream alteration agreements, a reclamation plan must be filed with the Reclamation Board before mining can commence.

Water laws in California do not allow appropriation for instream values, but only for uses which physically remove water from the channel. The Governor's Commission to Review Water Rights Law is drafting legislation which would provide for minimum instream flows essential for fish, wildlife, and recreational needs. The State Water Resources Control Board would be responsible for determining these flows (Schneider 1978). Allocations for competing uses of water will be made after the minimum

flow is established.

State Actions

The Resources Agency, charged by CEQA with protection and wise management of California's resources, houses the following departments: Conservation (including the Division of Mines and Geology which deals with gravel mining and reclamation plans), Fish and Game (responsible for reviewing proposed water projects for environmental impacts, for surveys of rare and endangered species of plants and animals, coordinating wild game management, and issuing stream alteration agreements), Parks and Recreation (responsible for providing recreational opportunities as well as preservation of natural ecosystems), Forestry (regulates timber harvesting and enforces the Forest Practice Act), and Water Resources (maintains flood control projects and oversees statewide water management programs). These are representative examples of Resources Agency responsibilities in riparian habitat management, and several are discussed in more detail elsewhere in the remaining text.

An interagency Upper Sacramento River Task Force was formed by the Resources Agency to coordinate federal, state, local and citizen recommendations for management of the riverine system consistent with wildlife, agricultural, recreational, and water delivery needs (Burns 1978). A final report on these findings will be available from the Resources Agency.

Also included in the Agency are boards and commissions which concern themselves with water quality and permits for projects in the major flood ways. The State Reclamation Board's responsibilities include controlling and conserving floodwaters, reducing flood water damage, reclaiming land, protecting land from flood water erosion, and controlling encroachments on flood plains and flood control project works such as levees, channels, and pumping plants in the central valley. This board enters into agreements with the Army Corps of Engineers to provide maintenance services for completed projects, to obtain lands, easements and rights of way. Historically, the Reclamation Board paid little attention to destruction of riparian habitats. In recent years, however, its members have begun to respond to public concerns for the environment. A good example of this response is a civil engineering study done for the board on retention of riparian vegetation as a means for controlling bank erosion at 38 sites along the upper Sacramento River (Murray et al. 1978). The board also acquires conservation easements as part of bank protection projects for the purpose of preserving habitat and providing open space.

Other state boards having impacts on river systems are the State Water Resources Control Board and nine Regional Water Quality Control Boards. Waste discharge requirements, including limits on sediment loads, silt deposits, tastes, odors and visible oil, scum, grease or foam, are set by these boards for projects such as bank protection work. A recent resolution (77-246) of the Central Valley Regional Water Quality Control Board recognized the importance of preserving and enhancing fish, wildlife and other aquatic resources. This led to order 78-44 which established discharge and benthic monitoring requirements on an Army Corps bank protection project between Chico Landing and Red Bluff on the Sacramento River. These water quality boards are also responsible for nearly 80% of California's 208 planning in rural areas (see discussion of 208 under Federal Policies). The remaining 20% of the state 208 plans are handled by eight regional entities discussed under Local Policies.

Also working with the Resources Agency is the California Water Commission, which advises the Governor and the Department of Water Resources director, coordinates the state's position on Federal project appropriations, and approves state loans and grants to local water agencies. In the legislative branch, separate committees review all legislation concerning water resources development and their effects on water quality and wildlife habitat. They are responsible for coordinating both state and federal legislation to insure that new laws are consistent with state policies.

California's water management policies are beginning to reflect a significant change in attitude toward flood control. At a 1978 conference, "Flood Management - Now and in the Future," non-structural alternatives and riparian vegetation protection were recurrent themes. Floodplain and watershed management were recognized as desirable and necessary for social, economic and environmental reasons. Proceedings of this conference are available from the Department of Water Resources, P. O. Box 388, Sacramento, California 95802.

Local Policies

County governments in California have used tax incentives authorized by the 1965 California Land Conservation Act (Gov't. Code Sect. 51200) to keep agricultural lands in production and to preserve open space. A similar limited term contract has been recommended by land managers as a means for preserving riparian lands for their wildlife and social values.

County General Plans, a legal requirement in California, provide potentially strong protection for riparian areas. An ordinance which specifically deals with floodplain zoning and

riparian vegetation becomes part of a county's General Plan, and the county may be taken to court for inadequate enforcement. Where zoning is enforced, landowners retain the right to restrict trespass, no land acquisition takes place, and the vegetation is protected. Three California counties have riparian tree ordinances (Napa Code 1974, Santa Cruz Code 1977, Shasta Code 1977), two counties have native tree protection ordinances (Riverside Code 1977, San Bernardino Code 1963), and others are drafting similar protection into their codes. A model County General Plan element for wildlife and fishery habitat areas was designed by the State Resources Agency and offered as an example to all the counties bordering the upper Sacramento River. Shasta County designed its own floodway ordinance (Shasta Code 1977) while the remaining four counties either rejected or agreed to study the model.

Enrollment in the National Flood Insurance Program is nearly complete in California. Counties and cities are encouraged to develop their own flood plain ordinances and management plans with assistance from the State Department of Water Resources and the Federal Insurance Administration, as discussed under Federal Policies. These plans, which emphasize avoidance of flood damage using non-structural alternatives such as flood proofing, zoning and relocation, often lead to open space, recreational, and wildlife uses of riparian lands.

Eight regional government associations are responsible for 208 planning to meet Federal Water Pollution Control Act requirements. They plan for approximately 20% of the state and handle all the major urban centers. Urban creeks and small watersheds are examined on a regional level, and overall impacts of projects can be seen on a cumulative basis.

Local Actions

Gravel mining has become a controversial issue in California because of its effects on riparian habitats, ground water recharge and land use patterns. As most of the major gravel bearing creeks have been dammed, replenishment of gravel beds does not occur. Most gravel beds in California, therefore, are being recognized as non-renewable resources. California sand and gravel miners must obtain permits from the State Reclamation Board and local agencies, usually the county planning department and Board of Supervisors. The Department of Fish and Game and the appropriate Regional Water Quality Control Board negotiate stream alteration agreements and standards for discharges into the waterway. These specifications must be agreed upon before the Reclamation Board permit is granted. Public hearings are held, and a reclamation plan must be filed with the county. In spite of these procedures, very few counties have established adequate guidelines for mining and site reclamation. Orange County has a gravel ordinance, but most of the creeks there are urban, channelized and no longer support riparian vegetation. In Yolo County, however, an ordinance was developed to deal specifically with rural creeks which still have riparian habitat values (Yolo Code 1978). This ordinance will have far reaching effects, as the highest quality construction gravels in California are found along Cache Creek which flows from the inner coast ranges toward the east and the Sacramento River.

Sonoma County's ordinance for regulating surface mining and reclamation was patterned after the Surface Mining and Reclamation Act of 1975 (Public Resources Code Sec. 2710 et seq), and is being used as a model ordinance by other counties (Sonoma Code 1978).

Local water districts may vary in specific powers, but in general they may do whatever is reasonably necessary to meet the water requirements of their service areas. This may include dam building, well drilling and water reclamation. Riparian vegetation is usually regarded as a competing user of water, and subsequently removed from sloughs and irrigation ditches. In areas of intensive agriculture, these may be the only riparian habitats remaining. The water district is governed by an elected board of directors and is funded by bonds or local taxes. Districts have no legal power to plan or control land use except through the public hearing process, and rarely participate in regional land or water use planning unless it directly affects their water supply.

Parks and recreation areas in cities and counties have preserved some remnants of riparian forests, but there are few guarantees that wildlife values will be protected. Local government policy usually favors heavy use and development of facilities rather than a natural setting. In some cases, fishing accesses have been the least destructive method of allowing public use while protecting natural habitat. One significant example of a successful urban river park is the American River Parkway, established in Sacramento in 1976. The concept originated in 1915, but remained undeveloped until the construction of Folsom Dam in the 1950's. Foresighted county supervisors saw the need to acquire and preserve lands along the river for open space and to control urban development in the floodway. The result is a thirty mile river park with picnic areas, hiking, bicycling, horseback riding, canoeing, fishing, and swimming as well as wildlife habitat. This plan has been adopted by the Department of Fish and Game as part of the Lower American River Waterway Management Plan for the California Wild and Scenic Rivers

System (Sparks, et al. 1977).

School districts have been involved with the establishment of creekside natural areas, and have published educational materials which are used by classes and the general public as well as by local government agencies. An example is the excellent guide to the botany, care and planting of native oaks, including the riparian valley oak, written by the Heritage Oaks Committee and published by the Sacramento County Office of Education (Heritage Oaks Comm. 1976).

STRATEGIES FOR PUBLIC INVOLVEMENT

Arousing public concern over riparian habitat destruction is relatively easy. Turning that concern into action, however, can be a frustrating experience. One reason for this difficulty is that most people would prefer to be out enjoying the natural world rather than sitting all day in a stuffy hearing room! As a result, many will profess their interest in protecting riparian habitats, but very few will actually carry through with an action. It is critical, therefore, to educate the conservationist about the ways she or he can act, and to provide some means for action to take place. The sections on Government Policies and Actions and Strategies for Public Involvement are intended to help in this regard. It must be emphasized that, unless actions are taken, riparian habitats won't be available for future enjoyment!

Another frustration arises when environmental activists are recognized as effective organizers and subsequently are brought into the government system as members of boards or as hired staff. This can leave a coalition leaderless unless others have been given enough experience to take control. It can also result in a false sense of security on the part of environmentalists, because they feel less urgency to pressure someone who already agrees with them. Conservationists must remember that our agency people need constant support and reminders in order to keep moving in the appropriate management directions!

Californians have developed five basic strategies to protect riparian habitats: participation, education, legislation, preservation, and restoration.

Participation

Participation in the environmental review process through testimony at public hearings is the most popular and uniformly successful strategy for riparian habitat protection. Gravel mining permits, bank protection work, levee encroachments, and flood plain management plans are examples of actions heard before boards and commissions at various levels of government. Testimony of environmentalists at these hearings has often introduced new data, resulting in the redesign of a project or the denial of a permit. Even large projects like the New Melones Dam on the Stanislaus River have been modified using the public hearing approach to focus national attention on the issues.

Letters from members of an environmental coalition to a government agency about a specific project or issue are extremely effective, and require relatively little effort. When the letter campaign is followed by someone's public testimony on behalf of the coalition, that person's comments are given considerable attention. Individual citizen participation in public hearings, however, is hampered by the nature of the process. Most hearings are held during the work day and few people can afford to leave their jobs on a regular basis to testify. Written testimony is an alternate way to have an impact, but it does not allow for open discussions that can favorably influence members of a board or commission. Meanwhile, the paid industry lobbyists are in attendance at every major hearing. A few large environmental groups have their own lobbyists, but they are often unable to cover all the important issues. Hearings, therefore, must be attended selectively, with emphasis on general policies and issues. Otherwise, they become energy draining and time wasting.

Membership on advisory committees and task forces, like the Upper Sacramento River Task Force, has been effective in cases where specific projects or development plans were being designed. For example, a Bureau of Reclamation seepage and drainage study now includes a nonstructural solution involving land use planning and wildlife habitat protection as a result of coordination between public advisory members and the Department of Fish and Game.

Working directly with agency staff on an individual basis or through public workshops is another valuable technique which allows the introduction of data and ideas from the inception of a project through to its completion. This also avoids conflicts later in the hearing room. Local agency people are often sympathetic to environmental concerns, and this leads to positive results like the riparian forest preserve established by the Army Corps of Engineers on the south fork of the Kern River. There is great potential for more preserves of this type in California, and the Corps has set an excellent example.

One area of public involvement which has grown significantly in the 1970's is attendance at government sponsored water-oriented workshops and conferences. Instream values, water management, flood control and water rights law are a few of the subjects which have attracted increasing numbers of environmentally aware citizens. These meetings are generally during the week and often require registration fees. They are usually designed for agency staff members who attend as part of their job and have their fees paid for them. Citizen attendance, therefore, depends on one's ability to pay and to take time off from other responsibilities.

How, under the present system, can public involvement be complete when the average citizen is systematically excluded from the policy forming and decision making processes?

In California, this challenge has been met especially well by the Resources Agency. Key agency staff coordinate with conservation groups to organize public action on specific issues. Army Corps of Engineers bank protection work on the Sacramento River is currently coming under attack from state and federal game and wildlife agencies and citizen conservationists alike, as a result of coordinated efforts.

Another method for involving the public is being tried by the Department of Fish and Game. In carrying out the directives of California's Riparian Habitat Study Bill (see Legislation), Fish and Game established a riparian task force to develop programs and procedures for the protection, maintenance, and restoration of California's riparian resource. Along with government wildlife experts, the task force includes conservationists who initiated and followed the original legislation. Public influence upon government policies and actions is achieved in this case through continuous involvement: from initiation of legislation to completion of the funded study. To achieve the desired goal of riparian habitat protection, government agency staff are wise to take advantage of and encourage energies and interests from the public sector.

Education

Education takes place primarily through conferences, lectures, publications and field trips. Two riparian forest conferences, organized by local chapters of the National Audubon Society, featured speakers from county, state and federal agencies, the scientific and university community, conservation groups and the general public. Topics ranged from geologic history, botany, and ornithology to politics and bank protection. Proceedings of both conferences were published and have achieved wide dispersal (Gaines 1976, Sands 1977). Slide shows and informal lectures are presented to garden clubs, arboretum societies, school classes, church groups and environmental organizations to educate the general public and gain political support for riparian protection.

Field trips to riparian forests and canoe excursions on rivers like the American and Sacramento have increased public awareness of the high values of these ecosystems. Several public schools conduct outdoor education programs in riparian parks, and some state and university campuses are sponsoring ecological research in riverine areas. Newspaper articles, newsletters and a television documentary have all served to educate people about riparian forests and their vulnerability.

Legislation

Legislation (AB 3147) to survey California's remaining riparian habitats was initiated by citizen action in 1976, and finally signed into law in the fall of 1978. This bill provides funds for a two year Department of Fish and Game study with action recommendations to the Legislature. Additional legislation will be needed to implement these recommendations. Although it is commonly known that riparian habitats are diminishing, very few data have been gathered to document their demise. The Fish and Game survey will undoubtedly reveal more about what isn't known, and stress the need for more research.

Political participation also takes place through the election process. Conservationists in elective office, such as County Supervisor, Planning Commissioner or City Council Member, can achieve significant preservation and sound management of riparian habitats. Flood plain zoning, land use restrictions, and gravel ordinances are potentially valuable tools of the elected official. However, legal actions such as zoning and short term leases are regarded as temporary measures while negotiations for permanent protection proceed.

Preservation

Preservation of riparian habitats has been accomplished through fee title acquisitions, easements, and gifts. On behalf of the Department of Fish and Game, the Wildlife Conservation Board has purchased several riparian parcels totaling about 500 acres along the upper Sacramento River. The Department of Parks and Recreation has acquired some significant portions of riparian forests along the lower Stanislaus River and the Sacramento River. These parks, Caswell and Woodson Bridge, allow the public a chance to experience true riverine

jungles.

The Unique Ecosystems Program, initiated by the United States Fish and Wildlife Service, has ranked three riparian habitats among the top ten ecosystems in California, and given them high priority for acquisition using Land and Water Conservation Funds. Nominations for this program have come from many National Audubon Chapters, the California Native Plant Society, the California Natural Areas Coordinating Council and private individuals as well as from government agencies. Lands acquired under this program would be managed by local entities, such as Audubon, on a cooperative basis with the Fish and Wildlife Service, and would become part of the National Wildlife Refuge System.

Riparian habitat easements have been negotiated by the Reclamation Board and the Nature Conservancy. Gifts of riparian lands to nonprofit organizations, however, are rare. Two examples are the Audubon Bobelaine Sanctuary on the Feather River and the Audubon Arneberg Refuge on the Sacramento River.

Government owned riparian lands are generally protected from urban development, but the vegetation and wildlife often are not. One notable exception is the Army Corps Kern River preserve mentioned previously. More public pressure and participation will be needed to insure protection of riparian habitats already in government ownership.

Another approach to preservation involves revision of current policies and practices. For example, efforts are underway to encourage the Department of Forestry to apply the Forest Practice Act more uniformly to riparian forest trees. Some revisions of levee maintenance manuals have occurred which allow retention of vegetation and dead snags with high wildlife value. By working closely with agency staff, citizen conservationists have had a positive influence on riparian habitat management policies.

Restoration

Restoration of damaged riparian areas is probably the most difficult protection strategy, but certainly it is one of the most rewarding. Urban creeks in California have been heavily impacted by housing developments and flood control projects, but where a natural streamcourse still remains, public attention can be focused. Fryer Creek in Sonoma County is a model example of neighborhood environmental action which resulted in revegetation of a one hundred foot buffer zone, purchased by the county. Restoration of a riparian forest along a rural creek is planned on the Davis campus of the University of California. Revegetation of natural levees and banks, where consistent with reasonable flood control measures, is also being proposed.

Perhaps the most important result of all these protection strategies has been the creation of a network of environmentalists learning to work with existing regulations, while modifying others, in order to protect riparian habitats in California. Organizations which have participated in the protection efforts discussed above include many local chapters of the National Audubon Society, the California Delta Coalition, California Trout, Friends of the River Coalition, Riverlands Council, Save Our Creeks Committee of America, The Nature Conservancy, Sierra Club, and the Warm Springs Dam Task Force.

CONCLUSION

Meeting the challenge to protect and manage riparian habitats in California depends ultimately on statewide land and water use planning. It is not enough just to enforce local flood plain zoning, gravel ordinances, and water quality guidelines; entire watersheds must be studied and treated as ecological units which transcend the confinements of arbitrary political boundaries (Jones 1978). Comprehensive watershed management will require unprecedented cooperation among local, state and federal governments, and will depend significantly upon the concern and involvement of an informed public!

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Value of Riparian Vegetation to Avian Populations Along the Sacramento River System[1]

Merlin Hehnke[2] and Charles P. Stone[3]

Abstract.--The purpose of this study was to determine the value of riparian habitat along the Sacramento River to birds. Comparisons of avian populations through the year on riparian and riprapped berms, and agricultural lands associated with each, were made. Avian diversity (species/ha) was 71 percent and avian density (total number of birds) 93 percent less, on riprapped than on riparian plots. Avian diversity was 32 percent and avian density 95 percent less, on agricultural lands associated with riprapped vegetation than on those associated with riparian. Spring and fall migratory peaks of bird density and diversity were higher in riparian and associated vegetation than in riprapped and associated vegetation. Riparian vegetation appears to control avian density and diversity in associated vegetation.

INTRODUCTION

The Sacramento River System is the largest watershed in California and is recognized as a resource of exceptional natural, as well as manmade, values. It presently drains 67,340 square kilometers of the Central Valley, the Coast Range, the Sierra Nevadas, and the Cascade Range. Prior to the impact of man, the mainstream of the Sacramento from Keswick Dam to Collinsville (483 river kilometers) supported a riparian forest of about 313,000 hectares (McGowan 1961, Thompson 1961, Smith 1977) comparable to some of the finest riparian habitat anywhere. Lush, often continuous, riparian woodlands of valley oak (_Quercus lobata_), interior live oak (_Q. wizlizenii_), California sycamore (_Platanus racemosa_), Oregon ash (_Fraxinus oregona_), cottonwood (_Populus fremontii_), alder (_Alnus rhombifolia_), and willow (_Salix_ spp.), usually ranged from 4-5 miles in width on natural levees formed by the System (Thompson 1977).

Because of ever-increasing demands for agricultural lands and timber, increased flood control, and the need for a water conveyance system from northern to southern California, drastic changes in the Sacramento River and associated vegetation have occurred. Mining, grazing, water pollution, urbanization, and recreation have accounted for further losses (Roberts et al. 1977). As of today, the riparian forest comprises only 4,856 hectares (Smith 1977, Roberts et al. 1977), or about 1.5 percent of the acreage originally available to wildlife. The remaining fragments generally form a belt less than 100 yards wide along the watercourses (Thompson 1977). A Sacramento River Task Force Special Report (Burns et al. 1975) indicated that about 3,642 hectares per year of riparian vegetation have been lost between Keswick Dam and Colusa over the past 20 years. At the present rate of destruction, nearly all riparian vegetation on the Sacramento River could be eliminated in the next 20 years.

The value of California riparian habitat to birds seems well established. Gaines (1974) found that the remaining cottonwood-willow riparian forest along the Sacramento River supported a density and diversity of breeding birds equal to or greater than those

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in other California habitats. Michny et al. (1975) found that riparian areas supported densities of birds in excess of a typical "high density area," as established by Peterson (1941). Alteration of riparian vegetation along the Sacramento through channel improvement resulted in fewer birds than would be found on one of Peterson's (1941) "low density areas" in one case, and reduced avian populations 75 to 80 percent in another case along the Kings River (Hines et al. 1966).

In 1974, a three-year study was initiated to determine the values of naturally vegetated and riprapped banks and berms and associated agricultural lands to avian populations. Plant species were recorded on each study site, baseline data were established, and the results of vegetational removal were also assessed. The results of the first year's study are summarized here.

METHODS

Study Areas

Eight sample plots were selected along the Sacramento River near Knights Landing, California, for intensive study (Fig. 1). The northernmost of the eight plots selected is 3.06 kilometers north and the southernmost is 1.6 kilometers south of Knight's Landing in Sutter and Yolo Counties, California. Plots averaged 402.3 meters in length and ranged from 30 to 39 meters in width. Riparian vegetation was present on two of the plots, grass and/or shrubs on two riprapped plots from which riparian vegetation identical to that on existing riparian plots had been removed, and agricultural crops on the remaining four plots (Figs. 2 and 3). Agricultural plots were located perpendicular to the River while riparian and grass/shrub (riprapped) plots were located parallel to the River. Two plots were located at each of four locations; each perpendicular agricultural plot was situated adjacent to a riparian or grass/shrub plot parallel to the River. All plots were located near identical agricultural vegetation.

Sampling of Vegetation

Riparian and riprapped plots parallel to River (Plots A-1, B-1, C-1, and D-1) were sampled via three line quadrats (Gates 1949, Greig-Smith 1957, Phillips 1959, and U.S. Forest Service 1959) in each plot (Table 1). Quadrats were 1.83 meters in width, 0.91 meters on each side of transect lines. The length of each quadrat varied with distance

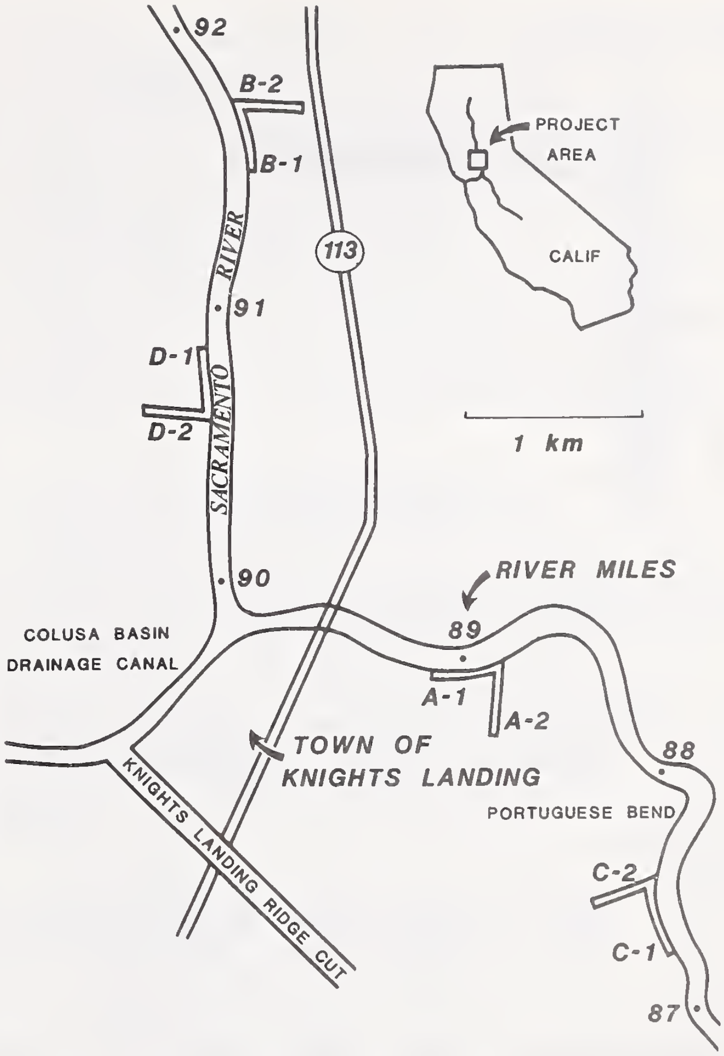

Figure 1. Avian survey plots in the vicinity of Knights Landing, California.

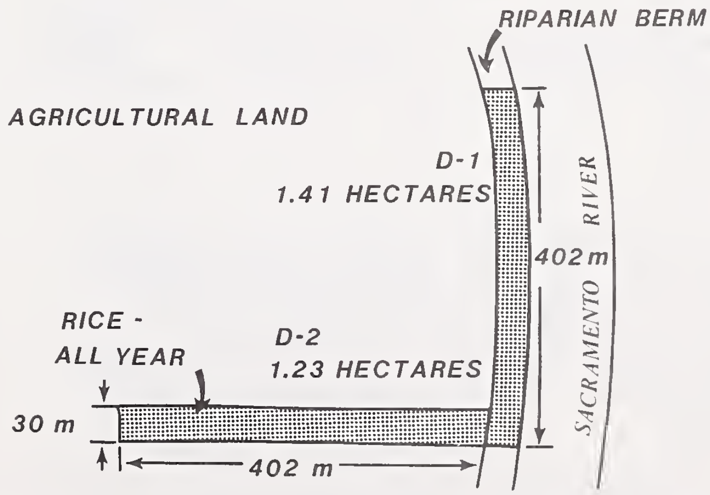

Figure 2. Location and arrangement of a riprapped and a riprapped-agricultural plot.

from the top of the levee to the low water line. River quadrats averaged 1.83 meters in width, 34.3 meters in length, and 62.8 square meters in area.

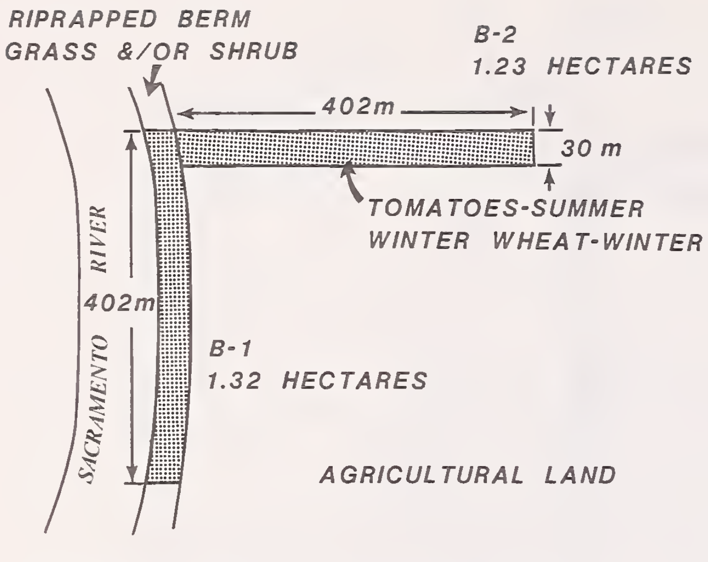

Figure 3. Location and arrangement of a riparian and a riparian-agriculture plot.

Table 1.--Summary of vegetation survey quadrat data.

Quadrat	WIDTH		LENGTH		AREA	
	(m)	(ft)	(m)	(ft)	Square meters	Square yards
Riparian and Riprapped areas						
1. A-1-A	1.83	6	34.4	113	62.9	75.3
2. A-1-B	"	"	32.9	108	60.2	72.0
3. A-1-C	"	"	34.1	112	62.5	74.7
4. B-1-A	"	"	34.4	113	62.9	75.3
5. B-1-B	"	"	31.1	102	56.8	68.0
6. B-1-C	"	"	32.9	108	60.2	72.0
7. C-1-A	"	"	33.2	109	60.8	72.7
8. C-1-B	"	"	35.1	115	64.1	76.7
9. C-1-C	"	"	38.7	127	70.8	84.7
10. D-1-A	"	"	34.1	112	62.5	74.7
11. D-1-B	"	"	36.0	118	65.8	78.7
12. D-1-C	"	"	35.1	115	64.1	76.7
AVERAGE	1.83	6	34.3	112.7	62.8	75.1
Agricultural Areas						
13. A-2-A	1.83	6	402.3	1320	736	880
14. B-2-A	"	"	"	"	"	"
15. C-2-A	"	"	"	"	"	"
16. D-2-A	"	"	"	"	"	"
AVERAGE	1.83	6	402.3	1320	736	880

Agricultural plots perpendicular to the River (A-2, B-2, C-2, and D-2) were sampled via one line quadrat in the center of each plot for the entire length of the plot. These quadrats averaged 1.83 meters in width, 402.3 meters in length, and 736 square meters in area.

All vegetation within each plot was recorded by species. Cover density was estimated by the "ocular estimation" technique (Webb 1942). Density classes used were: (1) Density T (trace) - leaves cover less than 1/80 of the area of the quadrat; (2) Density 1 - leaves cover 1/80 to 1/3 of the area of the quadrat; (3) Density 2 - leaves cover 1/3 to 2/3 of the area of the quadrat; (4) Density 3 - leaves cover more than 2/3 of the area of the quadrat.

After sampling each quadrat for species composition, coverage, and density, entire plots were checked for species not found on sample quadrats. All vegetation surveys were completed in the spring of 1975.

Sampling of Avian Populations

Rectangular sample plots (Pettingill 1970) of approximately 1.2 hectares were chosen on each study site. Levees or farm roads established one linear plot border and enhanced accuracy of plot definition. Each plot was censused 26 times or twice monthly in the 12+ month period from September 6, 1974, to August 22, 1975, between the hours of 6:00 a.m. and 12:00 p.m. The schedule was rigidly adhered to regardless of weather conditions.

Birds were identified by sight or sound while the observer walked in one direction to minimize duplication of recordings. Any birds observed but not identified were included in the total number of birds seen, but listed as species unidentified. Species and numbers of birds were recorded on a standard survey sheet. The order in which plots were counted was reversed on each census round to minimize time bias.

RESULTS

Sampling of Vegetation

Only riparian quadrats contained woody species, with overstory trees averaging 51.7 and midstory trees and shrubs 73.3 percent cover density (Table 2). Percent ground

Table 2.--Percent cover density[1] for plant strata in four vegetational types (summary of 16 quadrats surveyed during spring of 1975).

Habitat types	Overstory trees (%)	Midstory trees & shrubs (%)	Ground cover (grasses & sedges)
Riparian berms (Plots C-1 & D-1)	51.7	73.3	30.2
Riprapped berms (Plots A-1 & B-1)			81.5
Agricultural lands associated with riparian berms (Plots C-2 & D-2)			72.3[2]
Agricultural lands associated with riprapped berms (Plots A-2 & B-2)			74.1[2]

[1]Coverage density = $\frac{\text{(area covered by plant strata)}}{\text{(total area of berm)}}$ (100)

[2]Mainly agricultural plants.

cover on riparian plots (30.2) was considerably less than on agricultural lands (72.3-74.1) or riprapped berms (81.5). Fourteen species of woody plants were recorded on riparian berms (Table 3), with Fremont cottonwood and poison oak providing the most cover. Natural riparian habitat is typically layered, with cottonwood, sycamore, and arroyo willow overstory; saplings of

Table 3.--Dominant woody vegetation on 2 riparian plots located on the Sacramento River near Knights Landing, California.

	Common name	Scientific name	Density[1] on riparian berms
1.	Fremont Cottonwood	Populus fremontii	2
2.	Box Elder	Acer negundo	1
3.	Oregon Ash	Fraxinus latifolia	1
4.	Blue Elder Berry	Sambucus caerulea	1
5.	Longleaf Willow	Salix melanopsis	1
6.	Valley or Sandbar Willow	Salix hindsiana	1
7.	Arroyo Willow	Salix lasiolepis	1
8.	Common Fig	Ficus carica	1
9.	Poison Oak	Rhus diversiloba	2
10.	Coyote Bush	Baccharis pilularis	T
11.	Mule Fat	Baccharis viminea	T
12.	Calif. Wild Rose	Rosa californica	T
13.	Calif. Wild Grape	Vitis californica	1
14.	Calif. Wild Blackberry	Rubus vitifolius	1

[1]Densities: T (Trace) = Leaves cover less than 1/80 of the plot area.
1 = Leaves cover 1/80 to 1/3 of the area of the plot.
2 = Leaves cover 1/3 to 2/3 of the area of the plot.
3 = Leaves cover more than 2/3 of the area of the plot.

these species and box elder, Oregon ash and various shrubs as midstory; and poison oak, California blackberry, California wild rose, and mule fat as understory (Table 4).

Sampling of Avian Populations

During the 208 surveys (26 on each of 8 plots), 10,371 birds of 90 species were recorded (Table 5). The largest number of birds (5,441) was recorded on agricultural lands associated with riparian vegetation, and the lowest number of birds (254) was recorded on agricultural lands associated with riprapped berms. The number of species/hectare observed was greatest (32.1) in riparian vegetation, and least on riprapped berms (9.2). Fifty of the 90 avian species recorded in the riparian type were not recorded in any of the other habitat types. Woodpeckers, flycatchers, wrens, thrushes, vireos, warblers, and grosbeaks were among those dependent upon riparian types (Detailed information on seasonal abundance of each species by type is available in tabular form from the senior author).

About 85 percent of the total number of birds using agricultural lands were blackbirds and sparrows. Twelve species used agricultural lands associated with riparian vegetation but neither riprapped berms nor agricultural lands associated with them. Green herons, snow geese, wood ducks, Cooper's hawks, red-tailed hawks, merlins, rock doves, belted kingfishers, common flickers, California quails, red-winged blackbirds, and dark-eyed juncos were in this group.

The number of species per hectare (species density) on agricultural lands associated with riprapped berms was 32

Table 4. Predominant herbaceous vegetation on 16 vegetation quadrats from 8 plots located on the Sacramento River near Knights Landing, California.

	Common name	Scientific name	Density[1] on riparian berms	Density on riprapped berms	Agricultural lands associated with riparian berms	Agricultural lands associated with riprapped berms
1.	Wild Oat	Avena fatua	1	1		
2.	Ripgut	Bromus oliandus	1	1		
3.	Bermuda Grass	Cynodon dactylon	1	1		
4.	Wild Barley	Hordeum leporinum	1	1		
5.	Annual or Italian Ryegrass	Lolium multiflorum		1		
6.	Johnson Grass	Sorghum halepense		T		
7.	Garden Lippia	Lippia nodiflora		1		
8.	Horsetail	Equisetum laevigatum		1		
9.	Sorrel	Rumex crispus	1	1		
10.	Sky Lupine	Lupinus nanus	T			
11.	Bird Weed	Convolvulus arvensis	T	T		
12.	Star Thistle	Centaurea melitensis	T	1		
13.	Red Stem Filaree	Erodium cicutarium	T	1		
14.	Slender Wild Oat	Avena barbata	1	1		
15.	Black Mustard	Brassica nigren	T	T		
16.	Common Vetch	Vicia sativa	T	T		
17.	Carex Sedge	Carex barbarae	1			
18.	Tomato	Lycopersicon esculentum			2	2
19.	Rice	Oryza sativa			3	3
20.	Winter Wheat	Triticum aestivum			3	3

[1]Densities: T (Trace) = Leaves cover less than 1/80 of the area of plot.
1 = Leaves cover 1/80 to 1/3 of the area of the plot.
2 = Leaves cover 1/3 to 2/3 of the area of the plot.
3 = Leaves cover more than 2/3 of the area of the plot.

percent less than on agricultural lands associated with riparian vegetation (Table 5). Total number of species on agricultural lands associated with riprapped berms was also 32 percent less than on agricultural lands associated with riparian berms (Table 5), and total number of birds was about 95 percent less. Chi square analyses showed that avian density and diversity on agricultural lands associated with riparian vegetation both differed significantly ($p < 0.01$) from those on agricultural lands associated with riprapped berms.

Table 5.--Summary of first year's bird survey data (9/6/74 - 8/22/75) on riparian, riprapped, and agricultural plots near Knights Landing, California.

Habitat and plot	Hectares	Total # birds	Acc. Total # species	Total # birds/ha	Total # species/ha
Riprap (A-1)	1.3	186	20	143.0	15.4
Agricultural lands associated with riprap (A-2)	1.2	121	17	100.8	14.2
Riprap (B-1)	1.3	104	17	80.0	13.1
Agricultural lands associated with riprap (B-2)	1.2	133	18	110.8	15.0
Riparian (C-1)	1.4	2,048	76	1,462.8	54.3
Agricultural lands associated with riparian (C-2)	1.2	3,767	25	3,139.2	20.8
Riparian (0-1)	1.4	2,338	65	1,670.0	46.4
Agricultural lands associated with riparian (D-2)	1.2	1,674	33	1,395.0	27.5
Total Riprap (A-1 & B-1)	2.7	290	25	107.4	9.2
Total Riprap-Ag lands (A-2 & B-2)	2.4	254	25	105.8	10.4
Total Riparian (C-1 & 0-1)	2.8	4,386	90	1,566.4	32.1
Total Riparian-Ag Lands (C-2 & D-2)	2.4	5,441	37	2,267.1	15.4
TOTAL		10,371	90		

The number of species per hectare (species density) observed on riprapped berms was about 71 percent less than on riparian berms. The total number of species was about 72 percent less on riprapped berms than on riparian berms. Total number of birds was about 93 percent less on riprapped than on riparian plots. Chi square analyses revealed that there were significant differences ($p < 0.01$) in both avian diversity and density between riparian and riprapped berms.

Annual cycles of use for each of the four vegetational types are depicted in Figures 4 and 5. Avian densities and diversities varied through the year with food availability, amount of cover, and bird migration. In general, the expected spring and fall peaks in density and diversity occurred in each type, but were higher in riparian and associated agricultural vegetation than in riprapped and associated agricultural vegetation. The annual cycle of diversity on riparian berms and agricultural lands associated with them were correlated ($r = 0.84$, $p < 0.05$). Density data for the two types over the year were also correlated ($r = 0.87$, $p < 0.05$) when blackbird data were deleted, but not if they were included. Berms with riparian vegetation averaged 14 times the number of species (diversity index) of riprapped berms in the fall, 7 times in the winter, 4 times in the spring, and 3 times the number in the summer. Avian diversity on agricultural lands associated with riparian berms averaged 6 times that of agricultural lands associated with riprapped berms in the fall, 1.8 times in the winter, 1.3 times in the spring, and 1.5 times the number in the summer.

Avian densities throughout the year showed similar trends. Riparian berms averaged 35 times as many birds as riprapped berms in the fall, 11 times in the winter and summer, and 6 times in the spring. Avian densities on agricultural lands associated with riparian berms averaged 18 times as many birds as agricultural lands associated with riprapped berms (former riparian) in the fall, 10 times in the winter, 32 times in the spring, and 4 times in the summer.

Density disparity between riparian berms and riprapped berms was greatest in late September when riparian berms had 56 times as many birds as riprapped berms. Density disparity was lowest in late January when riparian berms contained only 1.3 times as many birds as riprapped berms. Similar disparities in diversity were noted, with 16 times as many species in riparian as in riprapped vegetation in late September and 3.8 times as many in late January. It is evident that timing of studies is very important in drawing conclusions about avian use of different vegetational types.

DISCUSSION

The basic three-layered composition of the riparian vegetation is partly a result of late winter and spring flooding that retards succession to even-aged cottonwood or to the valley oak type which supports a less diverse and dense avifauna (Gaines 1977). Avian density and diversity in the cottonwood-willow riparian vegetation were probably underestimated because of the dense vegetation; however, bird use data (60.2 bhd) were still in excess of the high density limits established by Peterson (1941). High bird species diversity is associated with vegetational layering (Walchuk 1970, MacArthur et al. 1962, and MacArthur 1964) and foliage volume, but other factors may also be involved (Gaines 1977). Some 67 species of birds are known to nest in the limited riparian forests of the Sacramento Valley (Gaines 1977). This is about 24 percent of the 277 regular nesters in California (Small 1974).

As indicated earlier, densities and diversities of birds on agricultural lands associated with riparian berms were correlated

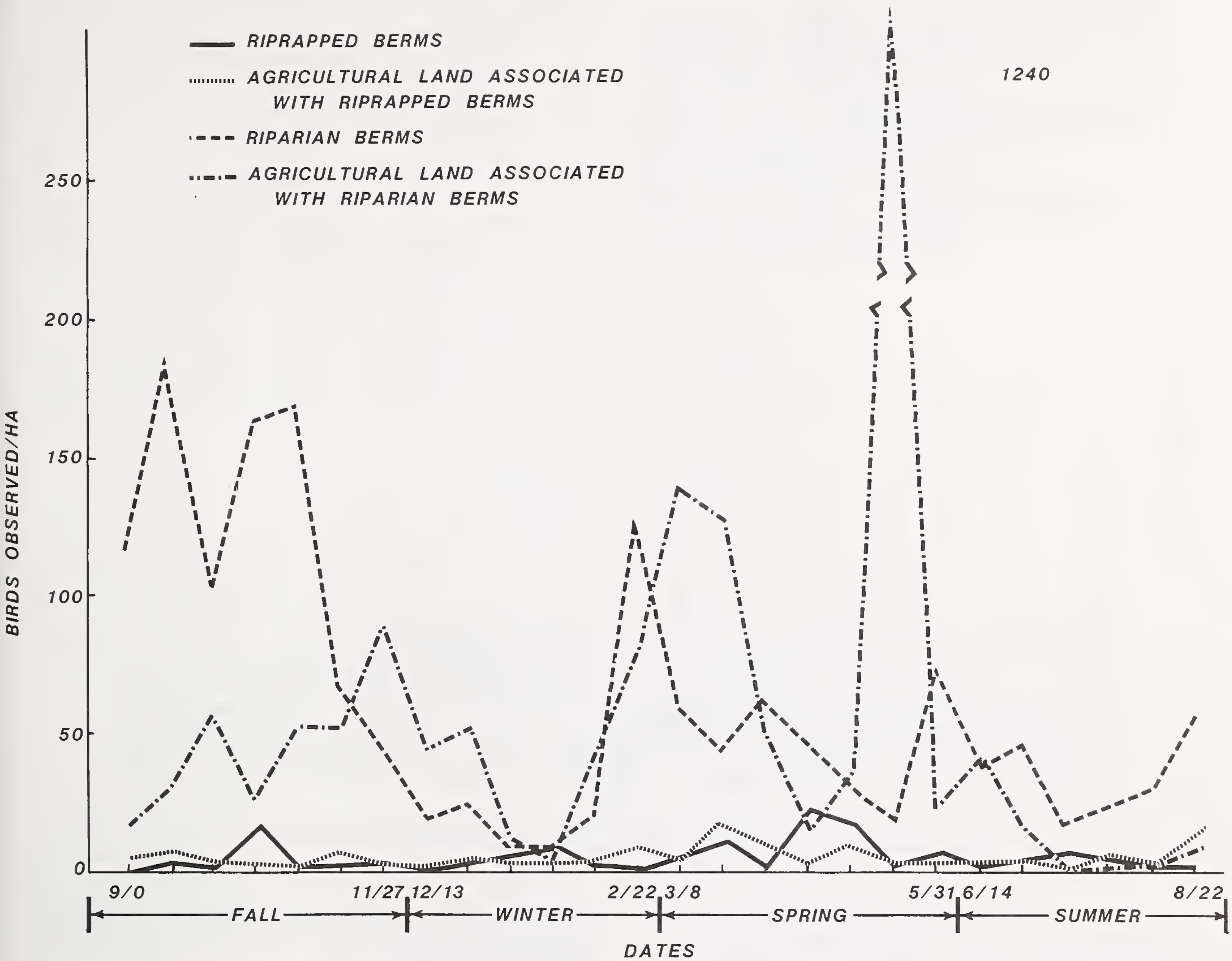

Figure 4. Numbers of birds/hectare observed on sample plots throughout the year.

with those found on riparian berms themselves throughout the year. The effects of "edge" surrounding riparian lands on birds found within riparian habitat seem minor (Gaines 1977) in this study, but the opposite effect on agricultural lands is striking. Not only were 93 percent fewer birds and 72 percent fewer species found on berms from which riparian vegetation had been removed, but on agricultural lands in association with rip-rapped berms, there were 95 percent fewer birds and 32 percent fewer species than on agricultural lands in association with riparian vegetation. Riparian vegetation appears to be the major factor controlling avian diversity and density in the Sacramento Basin. The value of riparian vegetation to avian populations is evident, especially when the alternative of little or no vegetation resulting from the removal of riparian forests is considered.

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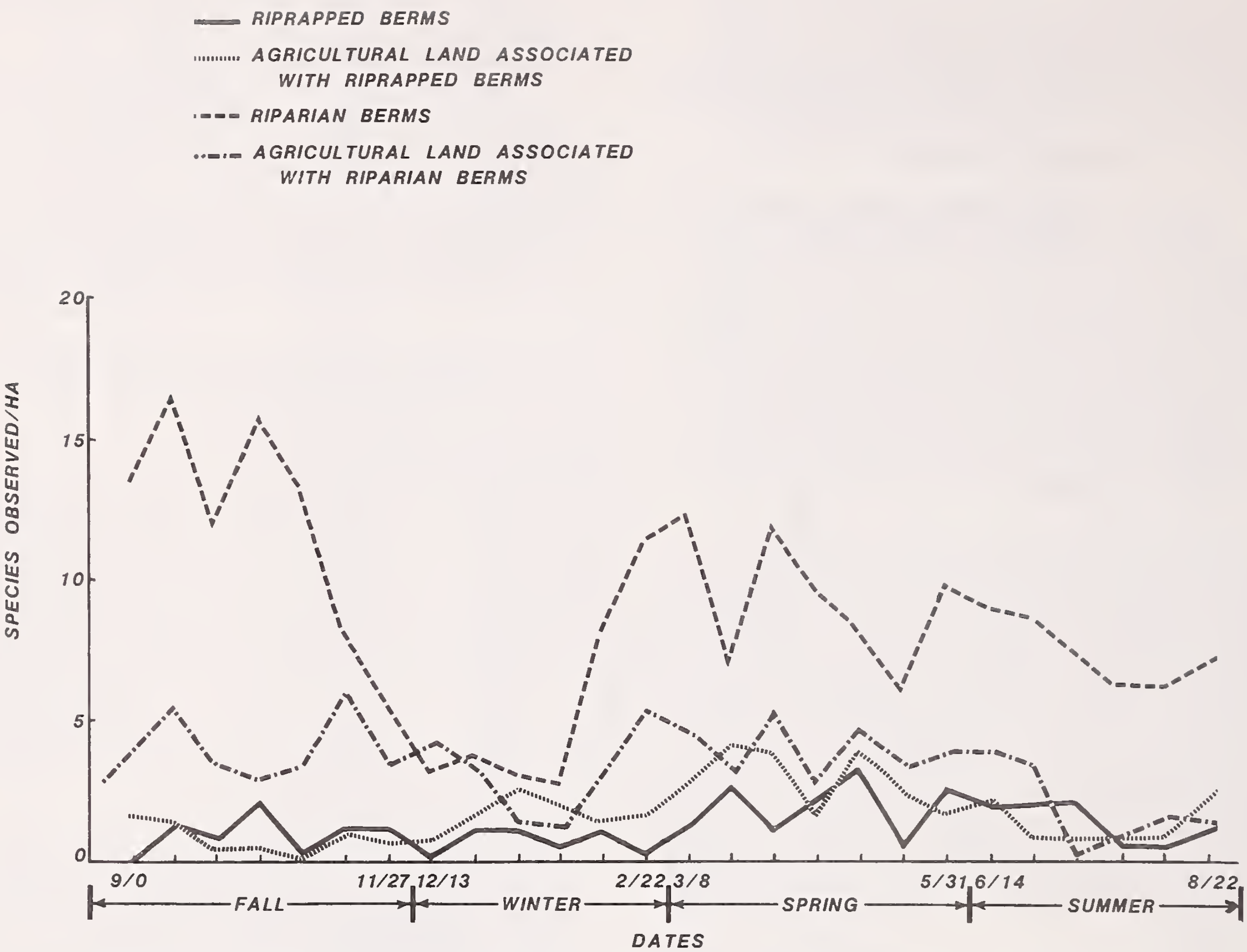

Figure 5. Numbers of species/hectare observed on sample plots throughout the year.

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Forest Management of Floodplain Sites in the Northeastern United States[1]

L. A. Morris, A. V. Mollitor, K. J. Johnson and A. L. Leaf[2]

Abstract.--Forestry related uses represent a suitable use for regulated floodplain lands. Because of the dynamic nature of floodplains, and the intrinsic relationship they have with our water resources, floodplain forest management presents unique problems and potentials. Management considerations involved in floodplain forestry are discussed and related to a system of classifying floodplain sites in the northeastern United States.

INTRODUCTION

During the past decade increased emphasis has been placed upon developing non-structural alternatives to flood control. Encouraged by federal programs which provide financial incentives for flood prevention planning, numerous local and state governments have adopted regulations restricting the use of floodplain areas. Forest management is suggested as a suitable use for these regulated floodplain lands (Soil Conservation Society of America 1971).

Floodplains occupy 129,150 ha, or about three percent of the total land area in the Northeast (U. S. Department of Agriculture 1962). These areas are productive agricultural lands. Traditionally, they have been fully utilized for crop production. A recent decline in agriculture across the region has resulted in the abandonment of many bottomland farms which have succeeded, or are in the process of succeeding to, forest communities. Forests now cover 13,000 ha of floodplain land. In light of the present trend in floodplain regulation, we can expect this forest resource to increase during the next 20 years. Under responsive management, these areas can provide timber, wildlife and recreational benefits while helping to reduce our flood control problems.

FOREST SITE CLASSIFICATION

Forest stand composition is determined by the response of individual tree species to variations in water availability and soil fertility. The large variation in these conditions characteristic of floodplains is reflected by the large number of tree species which occur on floodplains (tab. 1). If the occurrence of tree species are organized along a flood frequency gradient, as in figure 1, the importance of flood related characteristics to the development of floodplain forest communities becomes apparent.

Floodplain areas can be classified into five site types based upon site characteristics which are important in determining species composition and forest development (Morris 1978). As might be expected, these site types correspond to physiographic floodplain features which result from changes in sedimentation and developmental processes. The five types are:

- I Depressional swamps
- II Well drained silt flats
- III Frequently flooded point bars and rapidly aggrading alluvium
- IV Stable point bars
- V Pleistocene terraces

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[1]Paper presented to the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, GA., Dec. 11-13, 1978.

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Table 1.--Common floodplain forest species (after Morris 1978).

Scientific name	Common name(s)
Acer negundo L.	boxelder
Acer rubrum L.	red maple
Acer saccharinum L.	silver maple
Acer saccharum Marsh.	sugar maple
Alnus rugosa Du Roi	speckled alder
Betula nigra L.	river birch
Carya ovata (Mill) K. Koch	shagbark hickory
Carpinus caroliniana Walt.	blue beech, ironwood
Fraxinus americana L.	white ash
Fraxinus pennsylvanica Marsh.	green ash
Fraxinus nigra Marsh.	black ash
Juglans cinerea L.	butternut, white walnut
Juglans nigra L.	black walnut
Ostrya virginiana (Mill) K. Koch	hophornbeam
Pinus strobus L.	eastern white pine
Platanus occidentalis L.	American sycamore
Populus balsamifera L.	balsam poplar
Populus deltoides Bartr.	eastern cottonwood
Populus grandidentata Michx.	bigtooth aspen
Populus tremuloides Michx.	trembling aspen
Prunus pennsylvanica L. f.	pin cherry
Prunus serotina Ehrh.	black cherry
Prunus virginiana L.	choke cherry
Quercus alba L.	white oak
Quercus prinus L.	chesnut oak
Quercus rubra L.	northern red oak
Robinia pseudoacacia L.	black locust
Salix nigra Marsh.	black willow
Tilia americana L.	basswood
Ulmus americana L.	American elm, white elm

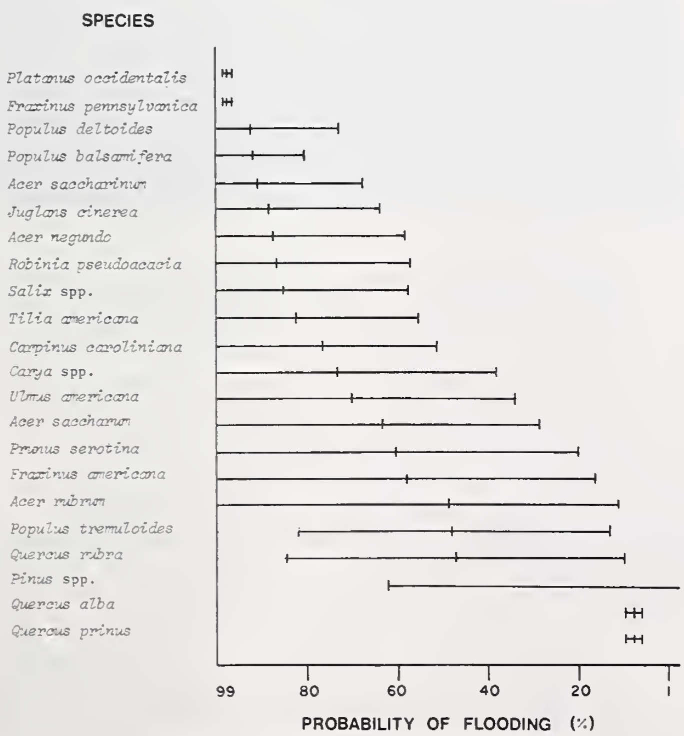

Figure 1.-- Ordination of tree species along a flood frequency gradient- mean value and one standard deviation indicated (after Morris 1978).

Figure 2 depicts the location of these site types on an idealized river floodplain. Important soil and vegetation characteristics associated with each site type are presented in table 2.

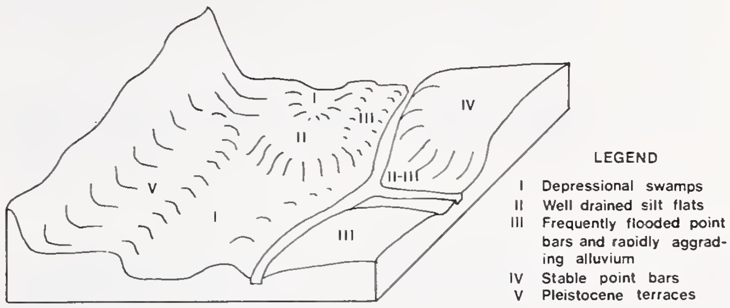

Figure 2.--Location of floodplain site types on an idealized river floodplain (after Morris 1978).

GENERAL MANAGEMENT CONSIDERATIONS

A river and its floodplain exist in a state of dynamic equilibrium. River flow velocity, channel width, channel depth, sediment load and nutrient concentrations have characteristic values at this equilibrium which can be modified by changes in floodplain vegetation.

Activities which deleteriously effect water quality are restricted by state and federal regulations through the Federal Water Pollution Control Act of 1972 and the Clean Water Act of 1977. Accelerated input of sediment and nutrients into waterways as a result of harvesting activities can be minimized by locating skid trails away from the channel and in a manner such that materials are not dragged through streams or up terrace scarps. Harvesting activities in a 20 meter wide strip adjacent to the channel should be limited. Complete removal of vegetation within this corridor increases channel erosion and thermal pollution (Campbell 1970). Although selection cutting may be acceptable, clearcutting is not a viable silvicultural option within these corridors. On other areas of the floodplain clearcutting is a useful management tool.

The use of fertilizers and herbicides is an acceptable practice on floodplains provided these materials do not enter the waterway. Aerial application should be discouraged in favor of ground application and direct injection methods. Fertilizer and herbicide treatments should not include the buffer strip immediately adjacent to the channel.

Table 2.--Characteristics of floodplain forest site types (after Morris 1978).

Site type	Physiographic location	Soil conditions	Dominant forest species	Productive potential
I	depressions on undifferentiated topstratum deposits	poorly drained silts, high organic matter and N content	*Salix* spp. *Acer saccharinum* *Populus deltoides* *Prunus serotina*	low, inadequate drainage
II	undifferentiated topstratum and confluence areas	well drained silts, high base content, near neutral soil reaction	*Acer saccharinum* *Populus deltoides* *Prunus serotina* *Fraxinus americana*	high, excellent overall fertility and moisture holding capacity
III	rapidly aggrading alluvial areas and point bars	mixtures of sand and silt, intermediate fertility	*Robinia pseudoacacia* *Acer saccharinum* *Ulmus americana* *Salix* spp.	moderate, strongly influenced by destructive flooding
IV	stable-infrequently flooded point bars	coarse textured sands, low fertility and available water holding capacity	*Acer saccharum* *Carya* spp. *Quercus* spp.	low, fertility and moisture holding capacity are limiting
V	seldom flooded Pleistocene terraces	mixtures of clay through gravel sized particles, developed B horizons high in K content	*Pinus* spp. *Quercus* spp. *Acer rubrum* *Prunus serotina*	high, moisture may be limiting at times

Changes in the vegetative condition of the floodplain are most strongly reflected in flood flow characteristics. During a flood event, the total discharge of the river is equal to the sum of the discharge of the normal channel plus the discharge of the adjacent floodplain. Growth of a forest on a floodplain which was formerly open cropland will increase the cross sectional area needed to accommodate a flood of a given discharge. Flood damages can be reduced if open stands are maintained adjacent to bridges or other structures which have inadequate clearance during flood flow regimes.

Some reduction in water yield will result from increased forestation of floodplains. This does not present a large problem in the Northeast. Only one percent of the water supply in this region is consumptively used at the present time (Water Resources Council 1968). Transpirational losses from floodplain forests will not jeopardize the supply of water for other uses.

Floodplain forests are recognized as important wildlife habitats, especially for avian populations (Carothers et al. 1974). Normally, small private owners require monetary incentives to carry out wildlife management projects on their land. As a result, wildlife management is seldom the primary management objective on upland sites. On floodplains, several programs provide funds for these projects. These include the Water Bank Program for Wetland Preservation, the Rural Environmental Conservation Program, and the Watershed Protection and Flood Prevention Act.

MANAGEMENT OF FLOODPLAIN SITE TYPES

The management program implemented on any forest area is based on a combination of the landowners wishes, the available financial resources, and the site's capabilities. On privately owned floodplain lands, management emphasis will normally be placed on the production of timber and fiber which generate a cash income. Publicly owned and managed floodplain lands can provide valuable recreation areas and aesthetically pleasing greenspace corridors. Once ownership objectives are defined and the economic constraints evaluated, several site related management options exist for each floodplain site type.

Type I - Depressional Swamps

Little potential exists for producing timber or fiber on the poorly drained areas characterizing this site type. *Acer saccharinum* and *Salix* provide a source of cordwood which can be regenerated by coppice methods (Fowells 1965). Other timber and fiber uses are less feasible on this site type.

The open crowned forests which dominate these sites are exceptional wildlife habitat. A heavy herbaceous ground cover exists, making these ideal nesting sites for waterfowl. Dead *Ulmus americana* and *Populus* stems are common on these areas and provide food and shelter for numerous species of songbirds (fig. 3). Wildlife habitat can be improved by limited cutting. Young stems of *Acer saccharinum* and *Salix* can be maintained as dense cover by frequent patch cutting. *Prunus serotina* can be favored as a food source by releasing it from competing vegetation. Snags should not be removed except where they constitute a hazard to adjacent timber by acting as a breeding sink for insects and disease, or, where they occur adjacent to trails. Patches of *Alnus* may be maintained as thrifty woodcock (*Philohela minor*) habitat by clearcutting on a 25 year rotation. Cuttings should be planned so that adjacent patches of *Alnus* are cut at five year intervals (Liscinsky 1972).

Figure 3.--Dead *Populus* stems, open canopy and heavy undergrowth typifying forest stands in depressional swamps.

Type II - Well Drained Silt Flats

The fertile well drained silts characteristic of these sites are potentially the most valuable floodplain areas for producing timber and fiber. A number of valuable species occur on this site type in associations representing distinct stages in the *Populus deltoides-Platinus occidentalis-Acer saccharinum*-mixed hardwoods succession described by Hosner and Minckler (1963). Accordingly, a number of timber management options exist.

Populus deltoides may be managed in short rotation even-aged stands. Highly shade intolerant, this species is normally reproduced through clearcutting and intensive cultivation for the new crop. Experience with *Populus deltoides* in the South suggests that mechanical site scarification with planting at two to three meter spacing may be required to establish this species on new sites. On sites where an adequate seed source exists, regeneration can be accomplished through site scarification alone. Removal of competing *Acer saccharinum* is necessary to prevent succession to a stand dominated by this species. Sample plot data indicate that *Populus deltoides* exceeding 50 centimeters dbh and 36 meters in height can be produced on a 30 year rotation (fig. 4).

Acer saccharinum stands dominate many areas within this site type. This large multi-stemmed tree, considered a valuable timber species in the Midwest (Illinois Technical Forestry Association, Inc. 1965) may prove to be equally as valuable in the Northeast. Moderately shade intolerant, *Acer saccharinum* can be propogated by either clearcutting or group selection uneven-aged management. If the option for uneven-aged management is chosen, care must be taken to open areas large enough for regeneration to occur. The optimal number of stems which should remain in the residual stand by size class are presented in table 3. Cuttings can be conducted in both even and uneven-aged stands at 10 year intervals. In even-aged stands these would be thinnings, and in uneven-aged stands these would constitute a cutting cycle (Illinois Technical Forestry Association, Inc. 1965).

Figure 4.--*Populus deltoides*, *Platanus occidentalis* and *Acer saccharinum* occurring on well drained silt flats.

Table 3.--Desirable stocking of residual stands for uneven aged management of bottomland hardwoods dominated by *Acer saccharinum* (after Illinois Technical Forestry Association 1965)

Tree diameter class (cm)	Number of stems/ha	Basal area (m^2/ha)
4-10	125	0.5
12-18	70	1.2
20-26	50	2.1
28-34	40	3.0
36-42	30	3.6
44-50	20	3.5
52-58	8	1.9
60-66	4	1.3
68-74	2	0.8
Totals	358	17.9

During late successional stages on the more mesic areas within this site type, *Acer saccharum, Prunus serotina* and *Fraxinus americana* may dominate the forest stand. Marquis et al. (1975) suggests a seed cutting 5 to 10 years prior to harvest for the purpose of encouraging regeneration of these species on upland sites. This technique is applicable on floodplain sites where these species occur. Selection cutting methods in stands dominated by these species will favor shade tolerant *Acer saccharum* in subsequent stands.

Juglans nigra at one time occupied fertile floodplain sites included within this site type. Planting this tree species provides a management alternative small landowners may find attractive.

The recreational values of this site type are limited. Forest stands dominated by *Populus deltoides* or *Acer saccharinum* are not aesthetically appealing. Dense undergrowth, including large areas of *Urtica* and *Toxicodendron radicans*, reduce their desirability as recreational areas.

Type III - Frequently Flooded Point Bars and Rapidly Aggrading Alluvium

Frequent flooding and unstable soil conditions limit many potential uses on these sites. Destructive flooding is more common than on other floodplain sites, and is reflected in lower basal areas and productivity of forest stands. Debris piles up to two meters high cover much of the site. This, coupled with the abundance of *Urtica* in the understory, make these sites aesthetically unattractive and undesirable for recreational uses (fig. 5).

Figure 5.--Heavy debris accumulation resulting from severe flooding on rapidly aggrading alluvial areas.

Even-aged management systems are most suited to the propogation of the shade intolerant species which occupy these sites. Management efforts should be concentrated on timber and polewood production with minimal capital investment. *Populus deltoides* can be reproduced successfully on these sites by clearcutting and site scarification. Natural seeding by receding floodwaters provide an adequate seed source on these frequently flooded sites which may be lacking on less frequently flooded sites. *Acer saccharinum* stands can be managed in the same manner described for stands dominated by this species which occur on well drained silt flats. *Robinia pseudoacacia* can provide a valuable source of polewood which sprouts readily after cutting. Release from competing vegetation is recommended for these coppice stands.

Type IV - Stable Point Bars

The low fertility and soil moisture availability occurring on floodplain areas within this site type is the primary factor limiting forest productivity. Management of these sites should favor species tolerant of these conditions. Where wildlife is an important consideration, excellent habitat for game birds and small mammals can be maintained by shelterwood or patch cutting of the *Acer saccharum, Quercus* and *Carya* which currently dominate this site type (fig. 6). Selection cutting will favor shade tolerant *Fagus grandifolia* and *Acer rubrum* and is not recommended.

Type V - Pleistocene terraces

This site type includes the most mesophytic areas of the floodplain. Disturbance by flooding is rare, and the forest understory lacks the heavy herbaceous growth which characterize more frequently flooded sites. These sites are

Figure 6.--*Acer saccharum, Carya* and *Quercus* occurring on infrequently flooded - stable point bars.

Figure 7.--Old field *Pinus strobus* occupying abandoned farmland on a seldom flooded Pleistocene terrace.

most suited to intensive recreational use. Because of the stable conditions picnic structures, paths or jogging trails would not likely be disturbed by flooding and would be easily maintained.

Forest management options on these sites are similar to those which exist on upland sites, and where they adjoin upland forests, they should be managed along with those stands. Many areas within this site type are characterized by a *Pinus* overstory with an understory comprised of *Pinus, Fraxinus americana, Quercus alba, Acer saccharum* and *Prunus serotina* (fig. 7). Little advantage exists in maintaining these terrace sites in *Pinus*, and timber management should be directed at maintaining a thrifty stand of upland hardwoods. Removal of the *Pinus* overstory will favor those hardwoods which respond well to thinning, such as *Fraxinus americana*. It, along with species of *Quercus* and *Acer saccharum*, will constitute the major proportion of the stand succeeding *Pinus*. These valuable species can be maintained by patch cutting. Selection cutting is not recommended as a silvicultural method as it will favor less desirable shade tolerant species including *Fagus grandifolia* and *Acer rubrum*.

CONCLUSIONS

Forest management is an acceptable use for regulated floodplain lands. Because of the unique relationship between floodplain vegetation and river characteristics, floodplain forest management presents unique problems and potentials.

Five floodplain site types can be recognized along rivers in the Northeast. They are: depressional swamps, well drained silt flats, frequently flooded point bars and rapidly aggrading alluvium, stable point bars, and Pleistocene terraces. Under proper management, these areas can provide timber, wildlife and recreational benefits with few adverse effects on the riparian ecosystem.

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Arizona State Park's Natural Area Program[1]

Patricia M. Bergthold[2]

Abstract.--A Natural Area Program within Arizona State Parks identifies and registers important sites within the State. Over half of the identified Natural Areas contain riparian elements. Developing protective strategies, cooperation with land managing agencies, and public education show promise for maintaining an important southwestern resource.

INTRODUCTION

Arizona is a spacially diverse land, with major biomes converging within her borders and a rich geologic history. The riparian ecosystems tie together four deserts, chaparral and grasslands with madrean and rocky mountain forests.

Arizona's arid climate has, in many ways, been a blessing. Impacts and development have been confined to a few, very specific areas: much of the natural landscape appears minimally disturbed. With 87% of the land in public ownership, an opportunity exists for a natural area program that is equalled in few other places in the world.

Arizona's claim to one of the nation's highest growth rates is presently placing demands on all resources. Governor Babbitt recently commented "Accommodation of reasonable growth, while conserving the very values for which people move to Arizona, is the challenge for Arizonans".

HISTORY OF NATURAL AREA PROGRAM

In 1971, the Natural Area Committee of the Arizona Academy of Science, recognizing the need to identify areas most important in Arizona by which environmental degradation may be measured, applied for a research grant from Arizona's Office of Economic Planning and Development (nee OEPAD) through HUD 701 land use planning funds. The Academy compiled studies of Established Natural Areas in Arizona (Smith, 1974) and identified additional sites for protection within the state. These 75 sites represent examples of the state's various ecosystems, important habitats, hydrologic and geologic structures presently in good condition and worthy of recognition and preservation (Smith, 1976).

The study produced management schemes for selected uses of natural areas and a numerical ranking scheme by which the sites could be prioritized to identify those most important and endangered.

At the completion of the contract in 1975, the Governor, by letter, asked Arizona State Parks Board to assume the program with a Natural Area Advisory Council, nominated by the Arizona Academy of Science, to assist the Board in their ongoing responsibility.

In 1976, the Parks Board formally adopted the program, and through the Council and Coordinator (half-time), continue to study additional areas, to recommend protective measures, and to register protected sites.

NATURAL AREA PROGRAM STRUCTURE

Natural Area Advisory Council

The ten-member Natural Area Advisory Council is comprised of geologists, hydrologists, ecologists, an archaeologist, land use and environmental education experts, who are drawn from various institutions and geographic areas within the state.

The Council gives proposed status to appropriate sites, defines policy and direction for the Natural Area Program; and, as individuals, contribute as consultants to natural area studies. Meetings, open to the public,

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[1]Paper presented at Symposium on Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, Georgia, December 11 - 13, 1978.

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are held three times per year, in various towns in Arizona.

The Council enacted goals and objectives, definitions, and criteria. The criteria incorporate the concepts of diversity, genetic pools, protection of undiscovered values, stable ecosystems, baseline monitoring, and include hydrologic, geologic and scenic values. Uses for Natural Areas may be scientific, ecucational, recreational, or serve as buffer or open space.

The Natural Area Program is not intended as a wilderness designation, although some areas may qualify. Many sites are close to cities, are small, or are disturbed. Additionally, sites were studied for, and boundaries drawn to include, intrinsic values. As a consequence, land ownership patterns within some areas are complex.

Selection Methodology

A potential natural area may be suggested by a private citizen, scientist, agency, or owner. A site is inventoried, and upon evaluation may be more completely studied for presentation to the Council for Proposed status. The study includes evaluation of climate, geology, floral and faunal components, history of disturbance, natural area qualities, ownership, present management, and suggested uses.

Increasing the political base for support of natural areas is one reason for opening nominations to the knowledgeable public. The other is to involve people and organizations throughout the state to enable better identification of potential Natural Areas.

The Brown and Lowe Digitized Computer-compatible Classification for Natural and Potential Vegetation in the Southwest, and map of the Biotic Communities of the Southwest, are the tools to identify the vegetational series and associations for representative natural areas. These important works are the basis of the Numerical Ranking Scheme (Smith, 1975).

The Numerical Ranking Scheme evaluates sites against each other to identify those most endangered or important. Scarceness or commonness of a biome, series or association, integrity, diversity or sensitivity to disturbance of a site, presence of rare, endangered or peripheral species; topographic diversity, hydrological processes, archaeological or paleontological values, threat, availability and use factors are evaluated and produce a value by which a site may be ranked.

Site Status

Proposed Natural Area status, a land use planning and notification step, is given to a site after the Council has reviewed the primary values, and assigns a numerical priority. Although this status has no actual impact or legal status, it serves to red-flag sites that might otherwise be overlooked during planning for long range public projects such as power lines, dams, and other consumptive uses. It calls attention to values that may not be apparent to agencies or owners, but that are important in the spectrum of sites in Arizona.

The second status with the Natural Area Program is "Recognized Natural Area". Owners or certain agencies (such as Indian reservations) may be protectively managing a natural area, but are hesitant to enter into an agreement with a governmental agency. This stewardship is acknowledged by awarding a "Certificate of Recognition".

The third status is "Registered Natural Area" whereby a document between State Parks Board and an owner/agency sets down specifics of a site's condition, management and important values. Although it is a non-binding agreement, several points within the document provide for communication and notification of management change. Mutual recognition of values, and the agreement to communicate are the keys for protection of sites held by others within the state.

Relationship to Federal Program

The various types of status within Arizona's Natural Area Program closely parallel those within the Heritage Conservation and Recreation Service's Natural Landmark Program, where land outside the agency's jurisdiction is identified for various values: geological or biological.

Federal agencies have policies and procedures for establishing natural areas on lands under their management. The U.S. Forest Service has two categories: Research Natural Area, and Botanical, Zoological or Geological Natural Area; Bureau of Land Management has Natural Areas and Areas of Critical Environmental Concern; and U.S. Fish & Wildlife Service and National Park Service may establish Natural Areas. The major vehicle for cooperation by these agencies is their incorporation of state-important natural areas within the scheme of their existing policies. In Arizona,

this is essential to the success of the Natural Area Program. Federal agencies do not have a state perspective to identify important sites within the state's range of natural systems; yet, with a major portion of Arizona's land in federal ownership, this cooperation must occur to protect the state's significant lands.

RIPARIAN ECOSYSTEM ISSUES IN ARIZONA

Background

During the past ten years, several government-sponsored projects in Arizona proposed to reduce riparian habitat. The public outcry in response to this action prompted important riparian ecosystem research sponsored by state and federal agencies.

The research produced startling figures supporting the need to identify and protect a heretofore unrecognized resource (Johnson, 1970).

Arizona's landscape supports limited perennial streams and riparian habitat (Brown, et al, 1978). Of the various ecosystems in the state, riparian areas occupy the smallest land area, less than .75% (Babcock, 1968). This is confined to narrow bands adjacent to the stream beds. In the arid southern half of the state, perennial streams and riparian habitat occur where geologic formations force water to the surface.

Land settlement patterns since earliest historic times centered on reliable water supplies, producing present private land ownership that closely follows stream and river drainages. Arizona faces the following dilemma: 87% of land base in public ownership, the majority of the most limited, most vulnerable and most valuable ecosystem (Riparian Habitat Symposium, 1977) is held within the private sector.

Recently, Governor Babbitt expressed concern for riparian habitat, noting its scarcity and lack of protection or standing in the state.[3]

Scope of Systems and Threat

The biotic range of riparian ecosystems in Arizona is diverse--from near alpine tundra to the palm grove remnants of evergreen subtropical forests. Most of the Sonoran desert rivers in the United States are located in southern Arizona. Significant portions of these rivers remain in a relatively natural state. The San Pedro River (with four proposed natural areas identified along Arizona reach(Smith, 1976)) occurs in a pivotal biotic area and supports record vertebrate diversity and significant acreage of mesquite forests.

The Natural Area Program has identified 45 proposed Natural Areas which include the range of Arizona's riparian ecosystems; half of the presently proposed 90 areas. Fifty percent of the 45 riparian areas are threatened by activities that may negate their values.

Present Utilization of Riparian Habitat

Livestock Grazing

Most riparian systems in Arizona are grazed, producing aging cottonwood or hardwood galleries, with concurrent lack of reproduction of trees, vines or shrubs; diminished wildlife and recreational values; and erosion and water quality problems. Much of the federal land is grazed; however, fencing certain riparian habitat is proposed or completed on various forests throughout the state (Ames, 1977). Other federal agencies, such as SCS, have counseled farmers or ranchers to remove "Phreatophytes"; a philosophy that is changing.

Groundwater Pumping

Primary users of groundwater are municipalities, industry (in Arizona, mining interests have water rights in several key riparian areas) and irrigated farming. Withdrawal of groundwater faster than plant roots can grow results in large dieoffs of natural riparian growth (Phillips, et al, 1964). Farming directly threatens the streamside forests by the clearing of new fields, or by farming to the edge of the stream banks. Federal Government agricultural policies directly or indirectly support groundwater withdrawal, compounding the complexity of efforts to conserve riparian habitat (Kendall, 1978).

Dams

Federal water management projects on desert river systems are the single most potent threat to riparian habitat in Arizona (Todd, 1978).

Present Protection Strategies

Federal Programs

The United States Forest Service in Arizona is fencing grazing exclosures on streams and adjacent riparian growth.

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[3]Speech to Governor's Commission on Arizona's Environment, August 10, 1978.

The U.S. Fish & Wildlife Service, through the unique and nationally significant ecosystem inventory, incorporates an analysis of riparian habitat for acquisition priority. In Arizona, private owners are aware of this option for maintaining or dispensing of important holdings.

In both programs, the Natural Area Program is supplying potential sites, justification and support for the federal action.

State Programs

The Natural Area Program calls attention to specific sites needing special planning or protection.

Arizona Game & Fish Department has long been a champion for protection of riparian ecosystems, and has been instrumental in mitigating impacts of several large federal projects (Manes, et al, 1970).

Private Programs

The Nature Conservancy has purchased and maintains several important properties in southern Arizona. Their ability to arrange financing for purchasing important habitat is an important role in the state.

A cattle ranching corporation, the Victorio Company, has fenced several stockponds to enhance riparian and wildlife habitat (Thomas, 1978). They are unique in the state, having several wildlife biologists on their ranches to manage for wildlife values, as well as livestock production.

Future Needs of Riparian Ecosystems

Federal Policies

Many federal agency programs that study, impact or enhance riparian habitat are not coordinated. A synthesis of the products of various programs' research with each other, and with the state can place dollars and efforts where it will be most beneficial to maintain riparian habitats.

State Policies

A state policy for riparian ecosystems would address:

1 - Legal recognition that maintenance of riparian vegetation and wildlife habitat is a beneficial use. This could set the stage for riparian habitat management agreements with entities that have discretionary land management capabilities. The mining industry presently leases farmable streamside land to maintain their right to the water by leasing to present "beneficial" users.

2 - Insuring that a voice knowledgeable of riparian ecosystem values is on water-related Boards and Commissions.

Research about the autecology of individual riparian species in the southwest. Proper management of this system depends on how the individual parts function. Specifically, it is not known at what age a cottonwood can withstand grazing. With this established, a rest-rotation grazing management plan on a riparian site can be developed.

During the next two years, the Nature Conservancy Heritage Program proposes to inventory the biological and geological elements within Arizona to identify those needing protection and planning consideration, and to computerize this information in an easily accessible mode. This valuable addition to Arizona's efforts should provide more information to document the need to establish a state riparian ecosystem policy.

SUMMARY

The Natural Area Program has established a statewide perspective and communication with federal and state agencies. Issues are clarified by understanding the policies and limitations of agencies, communication with the private sector and site documentation.

Riparian ecosystem policy and protection is the single most important issue for the Natural Area Program; the state's natural diversity is dependent on it. The focus of this symposium on management and protection strategies should serve to galvanize federal and state action for acknowledgement of this important ecosystem. Arizona requires federal understanding of its total riparian ecosystem needs because of the large federal holdings within the state. The state needs to define its role in the management and protection of its unique natural heritage.

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Responses of Riparian Species to Agricultural Habitat Conversions[1]

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Abstract.--Approximately 1100 ha of agricultural land and 540 ha of riparian habitats were censused over a 14-month period in the lower Colorado River Valley to examine relative use of these areas by riparian birds. We found that many species did not use agricultural lands at all; insectivorous species suffered severe losses through agricultural conversions, whereas fringillids, doves, some flycatchers, and the Brown-headed Cowbird used agricultural areas to a high degree. Riparian birds seemed to travel either very short distances into agricultural areas on rare occasions, or they frequently traveled great distances into those areas. Distance traveled from riparian vegetation was correlated with density and number of riparian species as were weedy margins, canals, and alfalfa (Medicago sativa). Also, agricultural-riparian edge was beneficial to certain species.

INTRODUCTION

Historically, riparian vegetation has been removed for many reasons (Ohmart, et al. 1977). More recently, riparian vegetation has often been cleared for agricultural purposes (approximately 1200 ha per year along the lower Colorado River). Natural ecosystems are challenged worldwide by the increasing demand for food and fiber by the ever burgeoning human population. Modern agricultural practices are less and less influenced by the constraints of natural systems and they present a real threat to wildlife existence (Davidson and Lloyd 1977).

A large portion of the lower Colorado River Valley is intensively farmed. Riparian communities are continuing to be extirpated, with a consequent loss of a certain segment of the riparian avifauna and replacement by other groups of birds. To date it is not known 1) which riparian species are lost when riparian vegetation is cleared; 2) if any riparian birds are benefited by adjacent agricultural land; 3) how far riparian birds will travel from riparian vegetation into agricultural areas; or 4) what factors (crops, weedy margins, farm buildings) in agricultural situations produce the most attractive situation for riparian birds. In this report we address only those questions concerned with the consequences of agricultural replacement of riparian vegetation to riparian bird species. In subsequent reports we will focus our attention on new bird species which are attracted to agricultural situations.

We census about 1700 ha of agricultural land every month along that portion of the Colorado River extending from Davis Dam, located on the Nevada and Arizona border, south to the International Boundary. Data for this report come from about 1100 ha of agricultural land located on the Colorado River Indian Reservation south of Parker, Yuma County, Arizona. Data were gathered each month between January 1977 and February 1978.

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METHODS

We censused nine transects totaling 43 km of agricultural land two or three times each month using a direct count technique. Density estimates (number of birds per 40 ha) for each month represent an average for censuses taken during a given month. Seven of the nine transects (each 4.8 km long) were located at different distances from riparian vegetation. The first was an agricultural-riparian vegetation edge; others were located at 0.4 km, 1.2 km, 1.6 km (2 transects), 2.0 km, and 2.4 km (2 transects) from riparian vegetation.

We censused a total of 5.8 km of transects in structural type IV cottonwood-willow (Populus fremontii-Salix spp.), 12.2 km of type IV honey mesquite (Prosopis velutina), and 3.1 km of type IV salt cedar (Tamarix chinensis) two or three times each month in the study area during the same period of time in order to obtain density and diversity of riparian birds. (For an explanation of how the vegetation was classified see Anderson, et al. 1977). Type IV vegetation was used for comparison with agricultural situations because it is the most common type in the lower Colorado River Valley (Anderson and Ohmart 1976). Density estimates (number of birds per 40 ha) represented averages of the monthly censuses. We used a modified Emlen census technique (Emlen 1971, 1977; Anderson, et al. 1977; Anderson and Ohmart 1977) for censusing riparian communities. For the sake of brevity, analysis of the other structural types is not dealt with herein. Censuses of agricultural-riparian edge situations were taken in January, March, June, July, October, November, December 1977 and January, February 1978.

In evaluating riparian species use of agricultural areas we first had to determine which species were "riparian." This determination was based on a list totaling 63 bird species present in cottonwood-willow, honey mesquite, and salt cedar communities over five seasons. Forty-one of these typical riparian species were present in agricultural areas at one or more seasons. The five seasons corresponded to major changes in avian community composition and population structure and included winter (December through February), spring (March, April), summer (May through July), late summer (August, September), and fall (October, November).

All swallows, swifts, hawks, falcons, shorebirds, wetland birds except marsh wrens, and species which only occurred as transients were omitted from the analysis. Monthly density estimates of each riparian species were determined for each of the five community types. The maximum distance (up to 2.4 km) to which each riparian species traveled into agricultural areas from riparian vegetation was recorded. We determined the average density of each species and the maximum distance traveled by summing the density of each species at its farthest distance and dividing by the number of months that the species traveled that far into agricultural areas. The average density throughout agricultural transects for a given species was incorporated for the corresponding months. An appearance at the greatest distance from riparian vegetation for a given species, even if it was only a single detection for one month, determined the maximum distance traveled.

Based on the number of months a species was present in agricultural areas relative to the number of months it was present in the valley, we devised a travel status for each riparian species observed in agricultural lands. We also did this in the riparian communities. Permanent residents included those species present in the river valley during all months, summer residents were those present for up to six months (April through September), and winter residents were those present for up to eight months (September through April). Where overlaps occurred, species were placed in the season representing their principal time of occurrence. Permanent residents observed in a particular community for only one to three months were considered rare in that community, those observed four to seven months were considered occasional, and those species present eight to 14 months were considered common. Summer residents observed in a particular habitat during only one month were considered rare, those observed two to three months were considered occasional, and those species observed four to six months were considered common in that community type. Winter residents present in a particular community type one to two months were considered rare; three to four months, occasional; and five to eight months, common. In the remainder of this report the term status will refer only to numbers of months present and will not be used to indicate numbers of individuals present during these months.

From the monthly composition of species and their status, we determined the time of year during which rare and occasional species traveled into agricultural areas. This was evaluated for annual residents only.

RESULTS

Seasonal Density and Diversity of Riparian Species Among Community Types

Seasonal densities of riparian species were consistently higher in the agricultural-riparian edge than in the other habitat types (fig. 1). Cottonwood-willow and honey mesquite densities were consistently higher than those in salt cedar and agricultural areas. Densities in salt cedar and agricultural areas were similar except in summer, when densities were greater in salt cedar. This is attributable almost entirely to the influx of large numbers of White-winged Doves (Zenaida asiatica) and Mourning Doves (Zenaida macroura) into salt cedar.

The density of White-crowned Sparrows (Zonotrichia leucophrys) and Gambel Quail

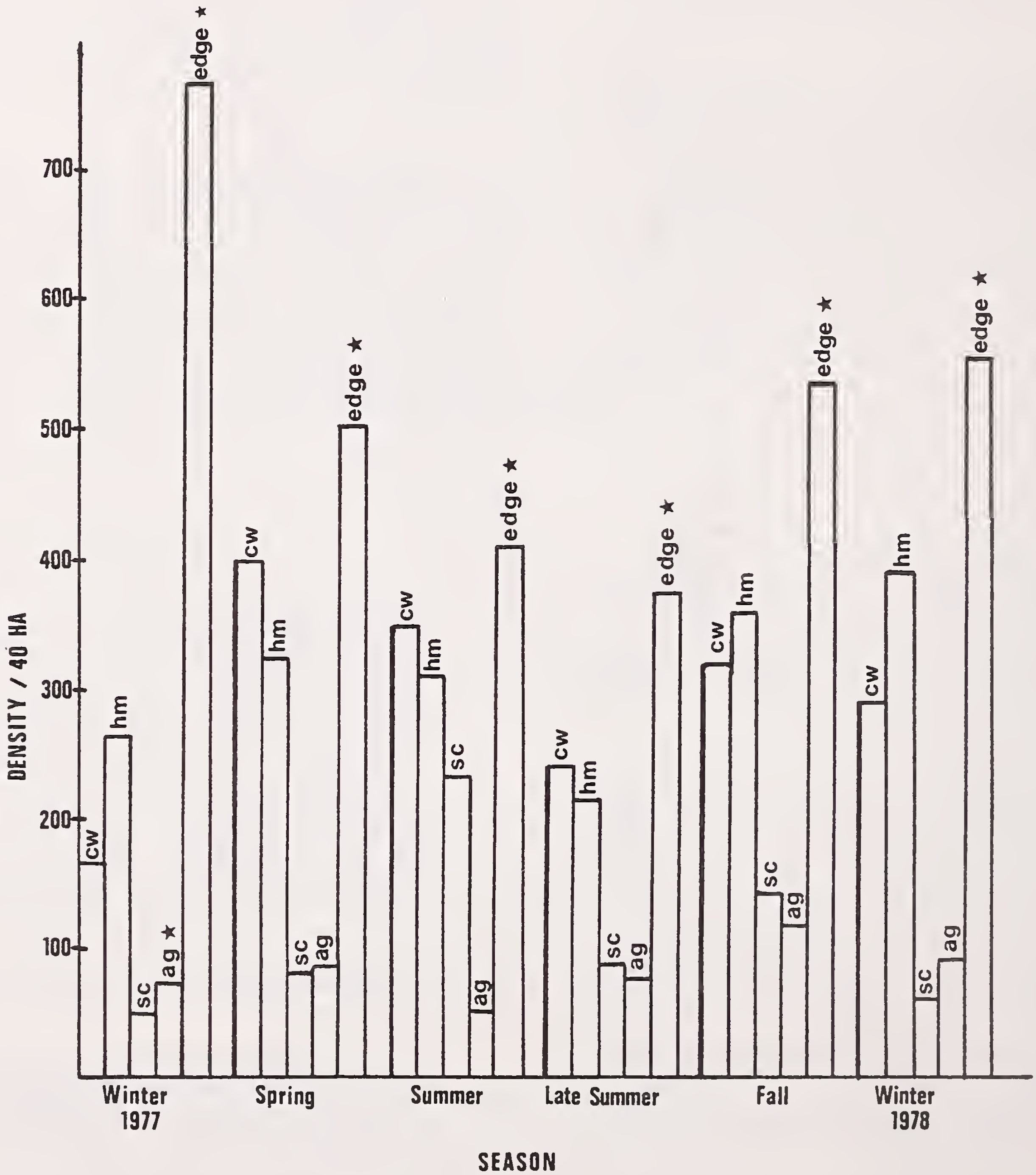

Figure 1.--The average seasonal density (n per 40 ha) of all riparian bird species in the riparian community types, agricultural areas, and the agricultural-riparian edge. Cw represents cottonwood-willow; hm, honey mesquite; sc, salt cedar; ag, agricultural areas. The * indicates that the average was for fewer months than all those included in the season.

(Lophortyx gambelii) were consistently largest in the agricultural riparian edge and accounted for a large proportion of the population in the edge community (Table 1). Other species with greatest densities in the agricultural-riparian edge during a majority of the months in which they were present in the valley included the Loggerhead Shrike (Lanius ludovicianus), Yellow-rumped Warbler (Dendroica coronata), Verdin (Auriparus flaviceps), and Brewer Sparrow (Spizella breweri). All of these species except the Verdin were considered common in agricultural areas and therefore seemed to benefit from the agricultural-riparian edge (Table 2). Verdins may benefit from the nearness of agricultural areas, but they rarely venture from the riparian vegetation into agricultural lands. The rest of the 35 riparian species showed a greater density in the riparian communities a majority of the months. Only seven riparian species (Ground Dove, Columbina passerina, Brewer Sparrow, House Finch, Carpodacus mexicanus, Western Kingbird, Tyrannus verticalis, Chipping Sparrow, Spizella passerina, Say Phoebe, Sayornis saya, and Brown-headed Cowbird, Molothrus ater) had a greater density in agricultural areas than in riparian communities for a majority of the months during which they were present.

Table 1.--The average seasonal density (n per 40 ha) of the Gambel Quail and White-crowned Sparrow in agricultural-riparian edge compared to average total density of riparian species there.

	Season					
Density	Winter 1977	Spring 1977	Summer 1977	Late Summer 1977	Fall 1977	Winter 1978
$\overline{X}$ Total Density Riparian Species	765	505	410	377	581	556
$\overline{X}$ Density White-crowned Sparrow	326 (42.6%)	192 (38.0%)	-	-	283 (48.7%)	247 (44.4%)
$\overline{X}$ Density Gambel Quail	59 (7.7%)	96 (19.0%)	76 (18.5%)	187 (49.6%)	61 (10.5%)	37 (6.7%)

Table 2.--The status of 41 riparian species in agricultural areas, the agricultural-riparian edge, and three riparian community types. (Code: R = rare; O = occasional; C = common.)

Species	Agricultural Areas	Edge	Cottonwood-Willow	Honey Mesquite	Salt Cedar
Permanent Residents					
Gambel Quail, Lophortyx gambelii	C	C	C	C	C
Mourning Dove, Zenaida macroura	C	C	C	C	C
Ground Dove, Columbina passerina	O	R	R	O	O
Inca Dove, Scardafella inca	R	-	R	R	R
Roadrunner, Geococcyx californianus	C	C	O	C	O
Common Flicker, Colaptes auratus	O	O	C	C	C
Gila Woodpecker, Melanerpes uropygialis	R	R	C	C	R
Ladder-backed Woodpecker, Picoides scalaris	R	C	C	C	C
Black Phoebe, Sayornis nigricans	O	O	C	R	R
Verdin, Auriparus flaviceps	R	C	C	C	C
Cactus Wren, Campylorhynchus brunneicapillus	R	O	O	C	O
Long-billed Marsh Wren, Cistothorus palustris	O	R	C	R	R
Mockingbird, Mimus polyglottos	O	O	R	C	R
Crissal Thrasher, Toxostoma dorsale	R	C	C	C	C

Table 2. Continued.

Species	Agricultural Areas	Edge	Cottonwood-Willow	Honey Mesquite	Salt Cedar
Permanent Residents (Continued)					
Black-tailed Gnatcatcher, Polioptila melanura	R	C	C	C	C
Loggerhead Shrike, Lanius ludovicianus	C	C	C	C	O
Brown-headed Cowbird, Molothrus ater	C	O	O	O	O
House Finch, Carpodacus mexicanus	C	O	O	O	O
Abert Towhee, Pipilo aberti	C	C	C	C	C
Summer Residents (April - September)					
White-winged Dove, Zenaida asiatica	C	C	C	C	C
Lesser Nighthawk, Chordeiles acutipennis	O	-	O	C	C
Ash-throated Flycatcher, Myiarchus cinerascens	R	C	C	C	C
Wied Crested Flycatcher, Myiarchus tyrannulus	R	-	C	-	-
Western Kingbird, Tyrannus verticalis	C	C	C	O	R
Northern Oriole, Icterus galbula	C	C	C	C	O
Summer Tanager, Piranga rubra	R	-	C	R	R
Blue Grosbeak, Guiraca caerulea	O	C	C	O	C
Winter Residents (September/October - April)					
Say Phoebe, Sayornis saya	C	C	C	R	O
House Wren, Troglodytes aedon	R	C	C	C	C
Bewick Wren, Thryomanes bewickii	R	C	C	C	C
American Robin, Turdus migratorius	R	-	C	C	O
Mountain Bluebird, Sialia currucoides	R	R	R	R	R
Ruby-crowned Kinglet, Regulus calendula	R	C	C	C	C
Orange-crowned Warbler, Vermivora celata	C	C	C	C	C
Yellow-rumped Warbler, Dendroica coronata	C	C	C	C	C
Sage Sparrow, Amphispiza belli	O	R	R	O	R
Dark-eyed Junco, Junco hyemalis	C	O	C	C	O
Chipping Sparrow, Spizella passerina	O	R	O	R	R
Brewer Sparrow, Spizella breweri	C	O	R	O	R
White-crowned Sparrow, Zonotrichia leucophrys	C	C	C	C	C
Lincoln Sparrow, Melospiza lincolnii	C	C	C	R	R

Species numbers showed a pattern similar to that exhibited by densities, with the exception of the agricultural-riparian edge (fig. 2); cottonwood-willow and honey mesquite communities had more riparian species than were found in agricultural areas and salt cedar. In four of the six seasons encompassed by the study presented in figure 2 (spring, summer and fall 1977 and winter 1977-78), agricultural areas and salt cedar had a number of species more similar to each other than to the other community types.

Agricultural situations and salt cedar had lower densities and number of species than other riparian community types. It may be more than coincidental that both of these communities are exotic in the valley.

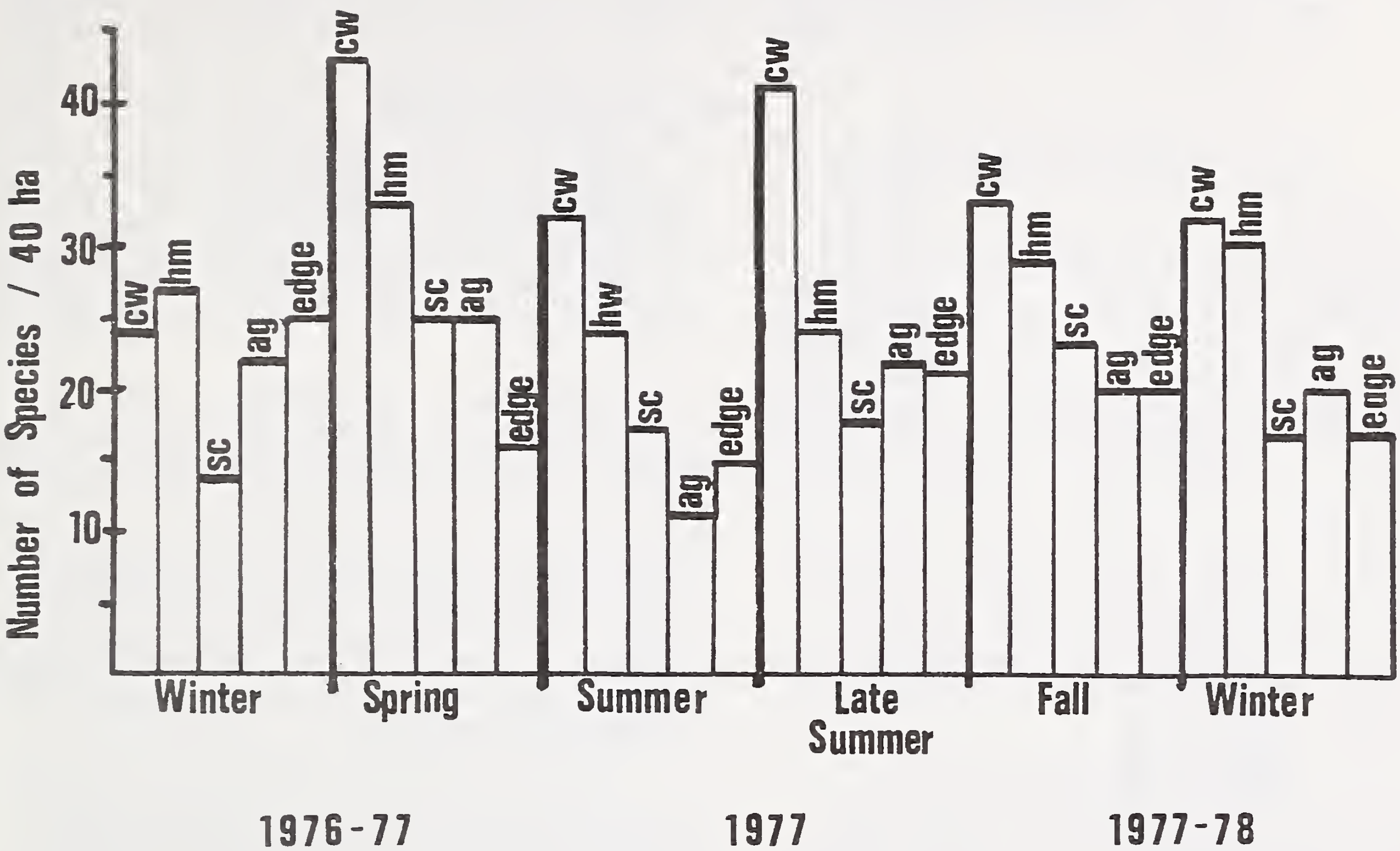

Figure 2.--The average number of riparian species (n per 40 ha) by season in the riparian community types, agricultural areas, and the agricultural-riparian edge. Cw represents cottonwood-willow; hm, honey mesquite; sc, salt cedar; ag, agricultural areas.

Status

The status of riparian species is presented in Table 2. Cottonwood-willow, honey mesquite, salt cedar, and the agricultural-riparian edge all shared 10 species, the status of which was lower in agricultural areas than in riparian vegetation (one tyrannid, two picids, seven insectivores), and all communities had only one species (a fringillid) whose status increased from riparian to agricultural areas. The proportions and composition of riparian species whose status either stayed the same or changed in the riparian communities relative to agricultural areas differed in each community (Appendix I).

The greatest proportion (37 percent) of species with an increased status in agricultural areas occurred in salt cedar (Table 3). Cottonwood-willow had the least (15 percent) species in this category. Cottonwood-willow and honey mesquite had the greatest number of species with an increased status in riparian habitat (42 percent and 34 percent, respectively). Thirty-two to 44 percent of the species had a similar status relative to agricultural lands in the riparian habitats.

Distance Traveled From Riparian Vegetation

For annual, summer, and permanent residents we attempted to determine the maximum travel distance from riparian vegetation for each species (fig. 3). These fall into two major groups: those which traveled up to 0.4 km (16 species), and those which traveled to nearly the maximum distance (2.4 km) from riparian vegetation (17 species). Additionally, 8 species traveled intermediate distances.

Of those species which traveled 0.4 km or less, 11 occurred rarely, 2 occurred occasionally, and 3 occurred commonly in agricultural areas. Of those species which traveled 2.0 to 2.4 km from riparian vegetation, 13 were common, 4 were occasional, and none were rare. Plainly, species which rarely use agricultural lands tend not to travel far into them (11 of 15 species) and species common in agricultural lands

Table 3.--Status summary of 41 riparian species in agricultural areas. Status is number of months present, not density. Species in each community type are compared relative to agricultural areas. Species numbers refer to increases or decreases from riparian to agricultural areas.

	Number of Riparian Species			
Community	Lower in Agricultural Areas	Equal in Agricultural Areas	Higher in Agricultural Areas	Total
Salt Cedar	13 (31.7%)	13 (31.7%)	15 (36.6%)	41
Honey Mesquite	14 (34.2%)	17 (41.4%)	10 (24.4%)	41
Cottonwood-Willow	17 (41.5%)	18 (43.9%)	6 (14.6%)	41
Agricultural-Riparian Edge	10 (24.4%)	18 (43.9%)	13 (31.7%)	41

generally travel throughout those areas (17 of 21 species). Species which occurred occasionally in agricultural areas showed no consistent pattern relative to distance traveled into those areas (fig. 3). All of the species which traveled less than 0.4 km had a rare status in agricultural areas.

Those species commonly occurring in agricultural lands but which did not travel far into those areas included the Roadrunner (Geococcyx californianus), Abert Towhee (Pipilo aberti), Gambel Quail, and Dark-eyed Junco (Junco hyemalis), all ground feeding species. Gambel Quail showed a concentrated density at the agricultural-riparian edge. Commonly occurring species which traveled throughout agricultural areas included 6 fringillids, 2 warblers, 2 doves, 2 flycatchers, the Brown-headed Cowbird, Northern Oriole (Icterus galbula), Loggerhead Shrike, Mockingbird (Mimus polyglottos), and Long-billed Marsh Wren (Cistothorus palustris).

Species traveling short distances into agricultural lands which had a rare status were 2 woodpeckers, 4 small insectivores, 2 flycatchers, the Mockingbird, Bewick Wren (Thryomanes bewickii), and Ground Dove. Rare species traveling farther into agricultural areas included the American Robin (Turdus migratorius), Summer Tanager (Piranga rubra), and Cactus Wren (Campylorhynchus brunneicapillus).

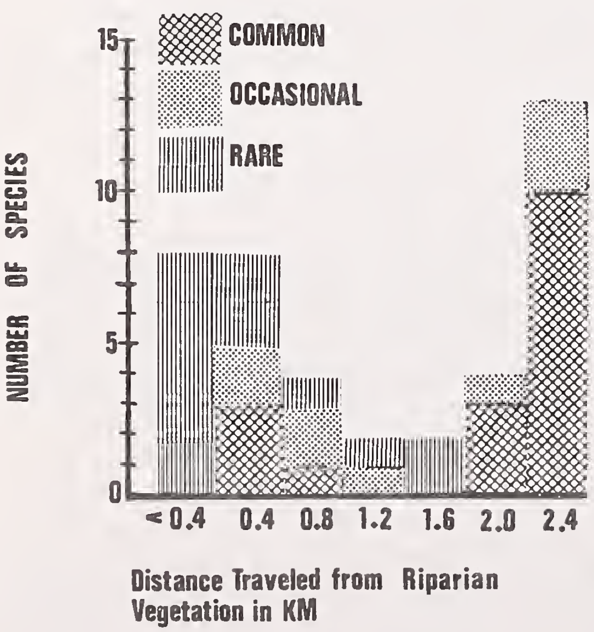

Figure 3.--The number of riparian species of each status (status throughout agricultural areas) and the maximum distance they traveled from riparian vegetation into agricultural areas.

Effect of Distances on Riparian Species Densities

We compared the average density of riparian species at their maximum distance from riparian vegetation and their average density throughout all of the agricultural areas censused. (Riparian species occurring rarely in agricultural areas were omitted from this analysis, as were those which traveled less than 0.4 km from riparian vegetation; the effect of distance on these species is obvious.) These two averages revealed that 54 percent (14 of 26) of the occasional and common status riparian species showed a lower density at maximum distance traveled into agricultural areas (fig. 4, Appendix II). Only 4 of the 9 fringillid species had smaller densities at maximum distances from riparian vegetation.

Seasonal Use of Agricultural Areas By Permanent Resident Riparian Species

Nineteen permanent resident riparian species occurred in agricultural situations;

seven of these occurred commonly, five occurred occasionally, and seven occurred rarely. A majority of the common users were in agricultural areas the year around; only the Loggerhead Shrike was present on a seasonal basis, from August through February. Of the occasional users, the Long-billed Marsh Wren was present in agricultural areas from October through February; the Black Phoebe (Sayornis nigricans) occurred only from December through March; the Common Flicker (Colaptes auratus) appeared in agricultural areas from October through March; the Mockingbird occurred only between March and September.

Species considered rare in riparian vegetation occurred in agricultural areas in winter and early spring months and/or September and/or October. Five rare species were in agricultural areas in the winter-early spring, five were in agricultural areas during late summer, and three rare status species were present once during both seasons.

Agricultural Factors Associated With Greatest Densities and Diversities of Riparian Species

Multiple regression analysis indicated that there were two primary factors correlated with densities and diversities of riparian birds in agricultural areas for each month. Distance from riparian vegetation was a factor most often correlated with both density and number of riparian species in agricultural situations (Tables 4 and 5). The presence of canals and weedy margins was among the most important

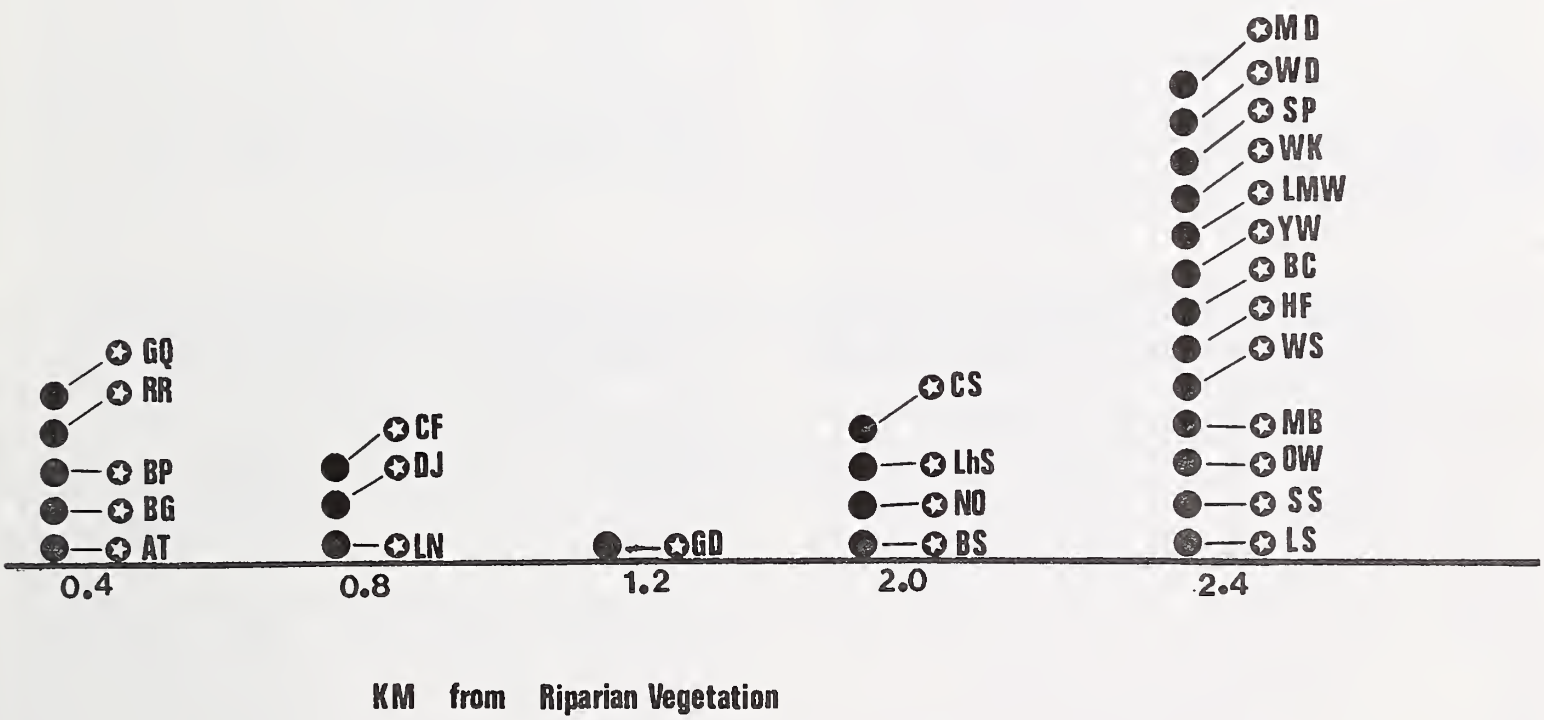

Figure 4.--Density changes of riparian species at their maximum distance traveled into agricultural areas from their density throughout agriculture. The horizontal lines mean that the density was the same or greater at the maximum distance. The angled lines mean a drop in density at the maximum distance. The species are placed at the maximum distance which they traveled into agricultural areas. Rare status species were omitted.

GQ=Gambel Quail	MD=Mourning Dove
RR=Roadrunner	WD=White-winged Dove
BP=Black Phoebe	SP=Say Phoebe
BG=Blue Grosbeak	WK=Western Kingbird
AT=Abert Towhee	LMW=Long-billed Marsh Wren
CF=Common Flicker	YW=Yellow-rumped Warbler
DJ=Dark-eyed Junco	BC=Brown-headed Cowbird
LN=Lesser Nighthawk	HF=House Finch
GD=Ground Dove	WS=White-crowned Sparrow
CS=Chipping Sparrow	MB=Mockingbird
LhS=Loggerhead Shrike	OW=Orange-crowned Warbler
NO=Northern Oriole	SS=Sage Sparrow
BS=Brewer Sparrow	LS=Lincoln Sparrow

Table 4.--Months when different field types and distance from riparian vegetation were the most important factors correlating with riparian species' densities in agricultural areas. The months for which R values are listed are the months when the test was significant ($p<0.05$ level).

	Year and Month													
	1977											1977	1978	
Factors	01	02	03	04	05	06	07	08	09	10	11	12	01	02
Distance	X	X	X	X		X	X	X*		X		X	X	
Canals	X	X					X	X		X	X		X	
Weedy Margins			X	X		X			X			X		X
Alfalfa					X			X	X					X
Pasture											X			
Wheat					X									
R^2 Value	0.869	0.824	0.737	-	-	0.483	0.451	-	-	-	-	0.667	0.505	-
R Value	0.928	0.908	0.858	-	-	0.695	0.671	-	-	-	-	0.817	0.711	-

*Those months with 3 field types had a field type as a most important factor with each of two other field types. The R values were exactly the same in the 2 sets of pairs. The starred field type was the one most important in both combinations.

Table 5.--Months when different field types and distance from riparian vegetation were the most important factors correlating with number of riparian species in agricultural areas. The months for which R values are listed are the months when the test was significant ($p<.0.05$ level).

	Year and Month													
	1977											1977	1978	
Factors	01	02	03	04	05	06	07	08	09	10	11	12	01	02
Distance	X	X	X	X	X	X*	X	X	X	X	X	X	X	X
Canals												X	X	
Weedy Margins	X					X	X							
Alfalfa		X	X	X				X	X		X		X	X
Pasture										X				
Inhabited Areas					X	X								
R^2 Value	0.640	-	-	-	0.827	0.727	0.716	0.735	0.755	0.785	0.579	0.842	0.814	-
R Value	0.800	-	-	-	0.910	0.852	0.846	0.857	0.869	0.886	0.761	0.918	0.902	-

*See note on Table 4.

factors correlated with density in 13 of 14 months (Table 4) and with number of species in 5 of 14 months (Table 5). The presence of alfalfa was an important factor correlated with density in four months; and with the number of species in 8 of 14 months. The density of riparian species was most often correlated with the presence of canals and weedy margins in conjunction with distance from riparian vegetation, whereas the number of riparian species was most often correlated with the presence of alfalfa in conjunction with canals and weedy margins and with the distance from riparian vegetation. Three other situations (presence

of pasture, wheat, or inhabited areas) were sporadically correlated with density and number of riparian species.

In 11 of 14 months, densities were dominated by one or two species (accounting for 46 percent or more of the total). In fall, winter, and spring, those species were the White-crowned Sparrow and/or Yellow-rumped Warbler, or Brown-headed Cowbird. In summer, densities were dominated by Mourning and White-winged doves. These species were strong influences on density correlations with field types.

In winter, early spring (March), and summer the correlations of agricultural situations with densities of riparian species were significant ($p \leq 0.05$), with the combined agricultural factors accounting for 45 to 87 percent of the variation in densities (Table 4) during these months. Significant correlations included only canals, weedy margins, and distance as most important factors. Densities of the above mentioned species were apparently enhanced by the presence of noncultivated situations (weedy margins and canals), especially when the areas were close to riparian vegetation.

From May through January the correlations with the number of riparian species were significant ($p \leq 0.05$), and the most significant pair of agricultural factors accounted for 58 to 84 percent of the variance, suggesting that distance from riparian vegetation in combination with one of the five field types was an important factor when considering number of riparian species present in agricultural areas (Table 3).

There was a greater number of significant correlations between agricultural variables and number of riparian species present than with density, and the correlations tended to be higher. This suggests that the complexity of factors involved in explaining the presence of riparian species may be less than the complexity of factors involved in explaining density of riparian species in agricultural areas.

DISCUSSION

In evaluating riparian bird use of agricultural areas, it is important 1) to consider the status and population level of the species in a riparian situation relative to that in agricultural areas, 2) to know when a species appears in agricultural areas, and 3) to realize whether its presence is directly related to the goals of agriculture or whether it is incidental or even antithetical to agricultural goals.

The value of agricultural situations to riparian species is limited if a species occurs in a high density in riparian habitat but occurs rarely in agricultural situations, or if a species occurs more commonly in agricultural areas compared to riparian habitat but in a lower density relative to other riparian communities. Additionally, if a species common in agricultural areas is there because of nearness to riparian vegetation (often a largely fortuitous matter) or because of the presence of weedy margins (a situation often opposed to agricultural goals), any apparent value of agricultural areas should be evaluated with caution.

Densities and Status

Our data showed that with respect to densities of riparian birds, agricultural situations did not support populations as large as most species in native riparian communities. There were 25 species whose status was similar or increased in agricultural areas relative to any one or more of the riparian community types, but 17 of these had lower densities in agricultural areas. Thus the value of agricultural areas to these birds is limited. If one defines a valuable habitat as one in which a species' density and status remains the same or increases relative to other habitats, there were only 8 (19.5 percent) of 41 riparian species observed in agricultural areas in this category. There were an additional 21 riparian species which did not use agricultural areas (Appendix III). The loss to agricultural areas of any community type of riparian vegetation analyzed herein would result in dramatic changes in the status and density of strictly insectivorous species.

Impact Caused by Loss of Salt Cedar

The loss of salt cedar to agricultural situations would be less detrimental to riparian species than loss of any other riparian community type. In fact, some species other than insectivores might be enhanced by such losses; there would be changes in species composition. This is not the case with loss of cottonwood-willow and honey mesquite communities. There were more species which preferred (as determined by frequency of appearance, not density) agricultural areas to salt cedar than there were species which preferred agricultural areas to cottonwood-willow or honey mesquite. Less than 20 percent of the species preferred agricultural areas to cottonwood-willow and approximately 25 percent preferred it to honey mesquite, whereas over 33 percent of the species

preferred agricultural areas to salt cedar. Although the greatest number of species were seen to hold a status in agricultural lands equivalent to honey mesquite, cottonwood-willow, and the riparian edge, it should be remembered that only a few of them had a density equivalent to or higher in agricultural areas as compared to the riparian communities.

Total Number of Birds in Agricultural Areas

The replacement of riparian vegetation by agricultural areas does not necessarily result in a decline in the total number of birds per unit area, because a different assemblage of species is attracted to agricultural areas. No matter how negative agricultural areas may be for riparian birds, it would be an error to assume that it has an overall negative value to birds in general. Data presentation and discussion are beyond the scope of this paper, but we have data (unpublished) which indicate that total bird densities in agricultural land often remain as high or higher than in riparian vegetation.

Effect of Agricultural-Riparian Edge

Agriculture is not entirely detrimental to all riparian species, since densities of some species increased in agricultural-riparian edge areas. Although these densities were dominated by a few species, all were found to be species having a common status in agricultural areas.

Agricultural-riparian situations could be used as a mitigating measure to offset losses due to agricultural encroachment. We have shown that the distance from riparian vegetation is important to density and number of riparian species in agricultural areas. The regression correlations coincide with observations that the average density decreased at maximum distance traveled in 54 percent of the riparian species. We know that if rarely visiting riparian species do go into agricultural areas they are not leaving riparian vegetation far behind. These findings, as well as knowledge that agricultural-riparian edges support a high density of riparian birds, suggest that an increase of agricultural-riparian ecotone acreage would be beneficial to riparian birds. If strips of riparian vegetation could be left at 1 km (half-mile) distances, relatively large densities of riparian species could be maintained, and birds which rarely use agricultural areas, as well as occasional and common ones, could venture into agricultural land when riparian land is cleared.

Importance of Alfalfa, Canals, and Weedy Margins

Regression analyses also revealed the potential importance of alfalfa, canals, and weedy margins to the number of riparian species present in agricultural areas. The value of alfalfa in attracting riparian species may be biased in that it is a field type often associated with weedy margins. So, whether the effect of alfalfa is contingent upon the presence of weedy margins or is solely because birds are attracted to alfalfa remains to be determined. Regression tests also suggest that the presence of canals and weedy margins enhances density and diversity of riparian species in agricultural situations. Weedy-margined agricultural areas, as opposed to cleared, barren areas, appear to be valuable in enhancing agricultural situations for riparian species.

Although these field types were correlated with density and number of riparian species in agricultural areas, the enhancement offered by them was beneficial to only a portion of birds in riparian habitat. These were the riparian species commonly seen in agricultural situations in high densities and which often showed no distance effects on their densities.

Seasonal Use of Agricultural Areas

For some species agricultural lands may not be considered a valuable habitat, but they nonetheless use it to a degree. Some annual residents use agricultural areas only on a seasonal basis. Insect biomass declined from late summer to lowest levels in winter and spring in all riparian communities (Anderson and Ohmart 1978). Berry-producing riparian vegetation is in fruit in winter. The Loggerhead Shrike, Long-billed Marsh Wren, Common Flicker, and Black Phoebe used agricultural areas only in periods of declining and low insect biomass. The Mockingbird used agricultural areas only during non-fruiting seasons for riparian vegetation. Similarly, when rare insectivorous species were in agricultural areas it was in winter and late summer. They, too, were using agricultural lands in periods of low food resource and in months during the post-breeding season. Perhaps food resource and dispersal pressures accounted for the presence of these species in agricultural situations.

In conclusion, our findings suggest that replacement of riparian vegetation has an overall negative impact on riparian avian species. Insectivorous species will be most drastically affected. Some of the loss is offset by the creation of agricultural-riparian edge in conjunction with main artery delivery canals, by the existence of weedy margins, and possibly by crops such as alfalfa. Agricultural land may serve as a food supplement to birds during winter when food resources are often depauperate for insectivores.

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Appendix I.--Status change (common, occasional, rare) in various community types relative to agricultural areas (Ag). The designations CW, HM, and SC refer to Cottonwood-willow, Honey Mesquite, and Salt Cedar communities, respectively.

Species whose status stayed the same in:

Ag-CW	Ag-HM	Ag-SC	Ag-Riparian Edge
Gambel Quail (*Lophortyx gambelii*)	Gambel Quail	Gambel Quail	Gambel Quail
Mourning Dove (*Zenaida macroura*)	Mourning Dove	Mourning Dove	Mourning Dove
White-winged Dove (*Zenaida asiatica*)	White-winged Dove	White-winged Dove	White-winged Dove
Inca Dove (*Scardafella inca*)	Inca Dove	Inca Dove	Roadrunner
Lesser Nighthawk (*Chordeiles acutipennis*)	Roadrunner	Ground Dove	Gila Woodpecker
Say Phoebe (*Sayornis saya*)	Wied Crested Flycatcher	Gila Woodpecker	Common Flicker
Western Kingbird (*Tyrannus verticalis*)	Mountain Bluebird	Wied Crested Flycatcher	Say Phoebe
Mountain Bluebird (*Sialia currucoides*)	Loggerhead Shrike	Mountain Bluebird	Black Phoebe
	Orange-crowned Warbler	Orange-crowned Warbler	Western Kingbird
	Yellow-rumped Warbler	Yellow-rumped Warbler	Mockingbird
	Northern Oriole	Summer Tanager	Mountain Bluebird
	Summer Tanager	Abert Towhee	Loggerhead Shrike
	Blue Grosbeak	White-crowned Sparrow	Orange-crowned Warbler
	Abert Towhee		Yellow-rumped Warbler
(Cont'd next page)	(Cont'd next page)		(Cont'd next page)

Species whose status stayed the same in (cont'd):

Ag-CW

Loggerhead Shrike (*Lanius ludovicianus*)

Orange-crowned Warbler (*Vermivora celata*)

Yellow-rumped Warbler (*Dendroica coronata*)

Northern Oriole (*Icterus galbula*)

House Finch (*Carpodacus mexicanus*)

Abert Towhee (*Pipilo aberti*)

Dark-eyed Junco (*Junco hyemalis*)

Chipping Sparrow (*Spizella passerina*)

White-crowned Sparrow (*Zonotrichia leucophrys*)

Lincoln Sparrow (*Melospiza lincolnii*)

Ag-HM

Sage Sparrow

Dark-eyed Junco

White-crowned Sparrow

Ag-SC

Ag-Riparian Edge

Northern Oriole

Abert Towhee

White-crowned Sparrow

Lincoln Sparrow

Species whose status was greater in the riparian:

Ag-CW

Gila Woodpecker (*Melanerpes uropygialis*)

Ladder-backed Woodpecker (*Picoides scalaris*)

Common Flicker (*Colaptes auratus*)

Ash-throated Flycatcher (*Myiarchus cinerascens*)

Wied Crested Flycatcher (*Myiarchus tyrannulus*)

Black Phoebe (*Sayornis nigricans*)

Verdin (*Auriparus flaviceps*)

House Wren (*Troglodytes aedon*)

Bewick Wren (*Thryomanes bewickii*)

Cactus Wren (*Campylorhynchus brunneicapillus*)

(Cont'd next page)

Ag-HM

Lesser Nighthawk

Gila Woodpecker

Ladder-backed Woodpecker

Common Flicker

Ash-throated Flycatcher

Verdin

House Wren

Bewick Wren

Cactus Wren

Mockingbird

Crissal Thrasher

American Robin

Black-tailed Gnatcatcher

Ruby-crowned Kinglet

Ag-SC

Lesser Nighthawk

Ladder-backed Woodpecker

Common Flicker

Ash-throated Flycatcher

Verdin

House Wren

Bewick Wren

Cactus Wren

Crissal Thrasher

American Robin

Black-tailed Gnatcatcher

Ruby-crowned Kinglet

Blue Grosbeak

Ag-Riparian Edge

Ladder-backed Woodpecker

Common Flicker

Ash-throated Flycatcher

Verdin

House Wren

Bewick Wren

Cactus Wren

Crissal Thrasher

Black-tailed Gnatcatcher

Ruby-crowned Kinglet

Blue Grosbeak

Species whose status was greater in the riparian (cont'd):

Ag-CW	Ag-HM	Ag-SC	Ag-Riparian Edge
Long-billed Marsh Wren (*Cistothorus palustris*			
Crissal Thrasher (*Toxostoma dorsale*)			
American Robin (*Turdus migratorius*)			
Black-tailed Gnatcatcher (*Polioptila melanura*)			
Ruby-crowned Kinglet (*Regulus calendula*)			
Summer Tanager (*Piranga rubra*)			
Blue Grosbeak (*Guiraca caerulea*)			

Species whose status was greater in agricultural areas:

Ag-CW	Ag-HM	Ag-SC	Ag-Riparian Edge
Ground Dove (*Columbina passerina*)	Ground Dove	Roadrunner	Ground Dove
Roadrunner (*Geococcyx californianus*)	Say Phoebe	Say Phoebe	Inca Dove
Mockingbird (*Mimus polyglottos*)	Black Phoebe	Black Phoebe	Lesser Nighthawk
Brown-headed Cowbird (*Molothrus ater*)	Western Kingbird	Western Kingbird	Wied Crested Flycatcher
Sage Sparrow (*Amphispiza belli*)	Long-billed Marsh Wren	Long-billed Marsh Wren	Long-billed Marsh Wren
Brewer Sparrow (*Spizella breweri*)	Brown-headed Cowbird	Mockingbird	American Robin
	House Finch	Loggerhead Shrike	Brown-headed Cowbird
	Chipping Sparrow	Northern Oriole	Summer Tanager
	Brewer Sparrow	Brown-headed Cowbird	House Finch
	Lincoln Sparrow	House Finch	Sage Sparrow
		Sage Sparrow	Dark-eyed Junco
		Dark-eyed Junco	Chipping Sparrow
		Chipping Sparrow	Brewer Sparrow
		Brewer Sparrow	
		Lincoln Sparrow	

Appendix II.--Average density (n/40 ha) of riparian species at maximum distances traveled from riparian vegetation into agricultural land and their average densities throughout agricultural land.

Species	$\overline{X}$ density at maximum distance from riparian vegetation	$\overline{X}$ density throughout agricultural areas
Gambel Quail	2	4
Mourning Dove	12	15
White-winged Dove	14	16
Ground Dove	2	2
Roadrunner	1	2
Lesser Nighthawk	1	1
Common Flicker	1	3
Black Phoebe	1	1
Say Phoebe	1	1
Western Kingbird	2	3
Long-billed Marsh Wren	1	3
Mockingbird	1	1
Loggerhead Shrike	1	1
Orange-crowned Warbler	1	1
Yellow-rumped Warbler	5	8
Northern Oriole	1	1
Brown-headed Cowbird	13	21
Blue Grosbeak	1	1
House Finch	5	7
Abert Towhee	1	1
Sage Sparrow	6	2
Dark-eyed Junco	1	3
Chipping Sparrow	5	6
Brewer Sparrow	5	5
White-crowned Sparrow	18	34
Lincoln Sparrow	4	2
Totals	106	145

Appendix III.--Riparian species lost with agricultural encroachment.

Yellow-billed Cuckoo (*Coccyzus americanus*)
Black-chinned Hummingbird (*Archilochus alexandri*)
Anna Hummingbird (*Calypte anna*)
Yellow-bellied Sapsucker (*Sphyrapicus varius*)
Brown Creeper (*Certhia familiaris*)
Hermit Thrush (*Catharus guttata*)
Western Bluebird (*Sialia mexicana*)
Blue-gray Gnatcatcher (*Polioptila caerulea*)
Cedar Waxwing (*Bombycilla cedrorum*)
Phainopepla (*Phainopepla nitens*)
Bell Vireo (*Vireo bellii*)
Lucy Warbler (*Vermivora luciae*)
Yellow-breasted Chat (*Icteria virens*)
Indigo Bunting (*Passerina cyanea*)
Evening Grosbeak (*Hesperiphona vespertina*)
Pine Siskin (*Carduelis pinus*)
Lesser Goldfinch (*Carduelis psaltria*)
Lawrence Goldfinch (*Carduelis lawrencei*)
Green-tailed Towheee (*Pipilo chlorurus*)
Rufous-sided Towhee (*Pipilo erythrophthalmus*)
Black-throated Sparrow (*Amphispiza bilineata*)

Grazing and the Riparian Zone: Impact and Management Perspectives[1]

Robert J. Behnke[2] and Robert F. Raleigh[3]

Abstract--Impacts of livestock overgrazing on riparian vegetation are magnified in arid and semi-arid regions. Typical stream habitat changes resulting from overgrazing of riparian vegetation, trampling of stream banks and increased erosion include: widening and shallowing of the stream bed, gradual stream channel trenching or braiding dependent upon soils and substrate composition, silt degradation of spawning and invertebrate food producing areas, loss of streamside and instream cover, increased water temperatures and velocities, decreased terrestrial food inputs, and a 3-4 fold decrease in trout biomass in grazed versus ungrazed areas. Recent livestock/fisheries study results and livestock grazing management options to repair, maintain and protect riparian habitats are presented.

A forum held in Denver, Colorado on November 3-4, 1978 brought together representatives of the livestock industry, range management agencies, fisheries and wildlife biologists, conservation organizations and the public. The forum was held to consider interactions between grazing and other riparian/stream ecosystem uses. Topics presented centered around the present condition of the public range lands, especially the riparian and stream habitats; recent trends in conditions; the relative impacts of grazing on riparian/stream ecosystems; and possible corrective measures. This paper presents the perspectives of two fisheries biologists on some of the issues raised at the forum and suggests some grazing management options to protect riparian/stream ecosystems from excessive grazing damage.

Nearly one-half of the total land area in the 11 western states is under Federal control, and more than 75% of this land is grazed by domestic livestock. It is our opinion that the use of public forage by private livestock is a valid and desirable use of these lands. Conflicts arise where livestock management practices ignore and/or destroy other equally valuable uses of the resource. Overgrazing of rangeland in the U.S. has resulted in 70 percent of western grazing lands producing less than 50 percent of their forage potential (Dregne 1978). Many livestock men and range managers have protested that figures quoted from studies such as Dregne's are overinflated. However, the condition of public grazing lands and the need for range improvements and more effective grazing management practices was documented as recently as 1974. The Bureau of Land Management (1975) reported that only 27.6 million acres of public range were in good to excellent condition while 135.3 million acres were in the unsatisfactory categories of fair or poor condition.

The same BLM report summarizes trends in range condition as follows: "In 1932 it was estimated that the western range had lost nearly 50 percent of its original productivity. Valuable perennial vegetation which formerly protected the soil surface was destroyed and was replaced by invading annual grasses, brush, and weeds. Range depletion was especially serious around the permanent water-holes and generally resulted in replacement of palatable forage species with undesirable brush and unpalatable forage plants."

"The inevitable results of overuse and depletion of the range were decreased vegetation and forage, accelerated soil erosion and runoff, and instability of the livestock industry dependent upon the public domain. A vicious circle of increasing use of a decreasing forage

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supply resulting in further depletion was established and continued unbroken until passage of the Taylor Grazing Act in 1934 made possible the control and regulation of range use on the public domain. One hundred years was considered a minimum of time needed to restore the public land to its original productivity. Such improvement could be attained only through management of grazing use, permitting the natural range restorative forces to operate, and applying artificial revegetation and other conservation practices to that part of the range where practices were feasible" (BLM 1975).

"Piecemeal attacks on the range problem have been made in the past, but this report has been prepared in the belief that only a comprehensive attack on the entire range program will suffice. Many conditions, forces, and problems are common to the entire western range country. Only through consideration of the whole is it possible to obtain a background and a grasp which will permit sound and lasting remedial action." "This statement was made almost 39 years ago (April 28, 1932) on page 1 of Senate Document No. 199 entitled The Western Range and could be restated today without any changes" (BLM 1975).

Congress and the President authorized $360 million this year for improvements on degraded public rangeland in the West. The monies were appropriated because of the Bureau of Land Management findings that 83% of the public grazing lands administered by BLM were in an unsatisfactory condition (GAO Report CED-77-88).

The overgrazing problem is focused most intensively on the productive riparian zone because livestock tend to concentrate along stream bottom lands. This situation is especially critical at lower elevations in arid and semi-arid regions where the grazing season is long and, by mid-summer, the only water and the majority of the palatable vegetation is found along streams. Other potential multiple use conflicts, such as logging, can occur and riparian communities still be preserved if certain guidelines pertaining to buffer strips are followed. There presently are no such guidelines or range management techniques in use short of fencing, that can protect riparian vegetation from overgrazing by domestic livestock.

The historic failure of Federal agencies to adequately protect the riparian zone of streams in livestock grazing areas, the common acceptance in range management practice that the riparian community is an unfortunate but unavoidable "sacrifice area," and the mass conversion in grazing practices to inadequately tested rest-rotation systems, is leading toward legal confrontations.

Unfortunately, the issue is charged with emotion and opinions soon become polarized with a "choosing of sides." Hopefully, as more light and less heat are shed on the matter, progressive ranchers will realize that livestock, as well as other interests, have a great deal to gain from the reversal of the downward trend in the vegetative conditions of watersheds and the restoration of grasslands from millions of acres of relatively unproductive public rangelands. The rate of "desertification" of the American Southwest, in the last 100 years, has been far more rapid than in similar climatic areas of the world-and overgrazing by domestic livestock is the major contributing factor.

THE PROBLEM

In areas where forage and water are well dispersed throughout the watershed and grazing intensity is well managed, livestock grazing is not harmful and can even be beneficial to certain fishery and wildlife values. It is primarily in arid and semi-arid regions that riparian vegetation is highly susceptible to overgrazing. Once the vegetation canopy is removed, heavy rains are not absorbed by the soil and run overland causing erosion. When this occurs, the amplitudes of peak runoffs are tremendously increased. The energy created by the increased flood peaks often cause the stream channel to either trench down, creating an arroyo, or if bedrock is near the surface, the energy is dissipated by forcing the stream channel to spread out and braid. If the stream channel is lowered to form an arroyo, the water table drops and the productive, palatable, riparian vegetation is replaced with less productive, less palatable, more xeric species. In addition, the loss of riparian vegetation results in destabilized streambanks. These dramatic changes in the watersheds and aquatic environments of the American Southwest during the past 100 years have been the major cause of the widespread replacement of native fishes by introduced species (Miller 1961; Behnke 1977). More specifically, trout populations, are affected from the loss of riparian vegetation and destabilized streambanks by a modification of their physical habitat; their abundance is habitat limited. Optimal trout waters are characterized by slow, cool, deep water with abundant cover typical of undercut bank areas. Trout populations in these habitats expand their populations to the limits of their food supply; their abundance is often food limited.

Several investigators have reported on the impacts of livestock overgrazing on riparian/stream ecosystems (Dahlem in press; Keller et al. in press; Marcuson 1976; Martin in press; Storch in press; VanVelson in press; and Winegar 1977). Typical stream habitat changes associated with overgrazing reported by these authors include:

1. Widening and shallowing of the streambed;
2. Gradual stream channel trenching or braiding dependent upon soils and substrate composition;
3. Silt degradation of spawning and invertebrate food producing areas;
4. Loss of streamside and instream cover;
5. Increased water temperatures and velocities;
6. Decreased terrestrial food inputs;
7. Reduction of 3 to 4 fold in trout biomass in grazed versus ungrazed stream sections;

In addition, the same studies have indicated that different classes of riparian habitats exist with differing characteristic resistences to grazing impacts.

Some livestock interests maintain that domestic livestock grazing is not the major cause of degraded range conditions on public lands. They contend that the original damage was done by large free-roaming herds of bison and is perpetuated by uncontrolled grazing of ungulates such as deer, elk, feral horses, and burros. Human uses of public lands such as driving off-road vehicles, fishing, camping, and picnicking are also considered major contributors to the destruction of range and riparian conditions. These uses certainly contribute to the problem but the primary cause of the deterioration of western rangelands was, and is, overgrazing by domestic livestock. This was particularly true in the late 19th century, during the days of the open range. Many people dispute this conclusion, but the evidence is overwhelming. Bison herds have been gone from the western ranges for over 100 years, and early descriptions of the Great Plains and western rangelands describe their productivity in glowing terms. The comparison of riparian/stream conditions within fenced exclosures, which exclude grazing by domestic livestock but not wildlife, with unfenced adjacent grazed areas or a visit to Yellowstone National Park with its abundant wildlife but no domestic livestock use, strongly indicates that wildlife use is not a major contributor to the degradation of riparian/stream habitats. Public use and grazing by feral livestock, where they occur, are localized problems.

Hastings (1959) concluded, after reviewing pertinent literature on the subject, that arguing over the question of whether or not livestock grazing was the major cause of the accelerated erosion in the arid Southwest was "beating a dead horse." Dissmeyer (1976) examined the causes of accelerated erosion on a watershed and concluded that 92% of the damage was due to livestock grazing. There is no other reasonable conclusion; the evidence is overwhelming.

THE PRESENT

The days of the open range came to an end in the 1930's. Substantial improvements in range conditions have been made since then in some areas, although comparable improvements in riparian vegetation in areas exposed to livestock grazing have not occurred. Riparian conditions continue to decline in many grazing areas.

It is now known that riparian/stream areas protected from livestock grazing can be restored in a very few years. The reestablishment of grasses and forbs as vegetative cover, stabilization of streambanks, transformation of intermittent flows to perennial flows, and reduction of sediment loads quickly occur in areas protected from overgrazing by livestock. The process of riparian and stream deterioration can quickly and effectively be reversed (Heede 1976; Winegar 1977). Papers presented at the Sparks, Nevada Livestock-Wildlife-Fisheries Symposium in 1977 documented the rapid response (within 3 to 5 years) of stream sections protected from livestock grazing with resulting increases in trout biomass of 3 to 4 fold. VanVelson (in press) discussed the dramatic habitat improvements in Otter Creek, Nebraska, a small tributary to Lake McConaughy, after the riparian area was protected from grazing in 1969. The Otter Creek area had previously suffered from overgrazing and the warm, shallow, silted stream was virtually barren of fish. The Nebraska Game and Parks Commission leased the headwater area in 1969 and fenced out livestock. The stream rapidly recovered as riparian vegetation flourished. The new vegetation helped stabilize the streambanks, narrowed and deepened the channel, cooled the water, and provided cover. The water ran cool and clean and gravel beds were exposed that had been covered by silt deposits for years. Rainbow trout fingerlings and eggs from Lake McConaughy were planted in Otter Creek over the next few years. A self-sustaining migratory run of rainbow trout from Lake McConaughy had become established in Otter Creek and added 20,000 young fish (7-10 inches in length) to the lake fishery in 1974.

Winegar (1977) reported similar beneficial results to water flows and habitat quality for fish and wildlife in the livestock exclosure zone on Camp Creek, Oregon. The abundance and diversity of wildlife in the protected riparian area was much greater than in contiguous areas still grazed by livestock.

Duff (in press) reported that riparian vegetation, particularly sedges and grasses, were significantly more abundant inside an exclosure on Big Creek in Utah after four years of rest. This riparian area changed in four years from bare, sparsely covered banks to luxuriant grassy overhang banks. Native willow plants that were severely grazed, decadent, or hedged back to basal stems responded more slowly. Willow stems had just begun to emerge through the streambank grasses and had a mean height of 50 centimeters at the end of four years of rest.

The exclosure fence was cut in 1974, and trespass livestock use occurred inside the exclosure during May and June. The livestock completely eliminated the woody riparian vegetation (willows) and reduced the grass-sedge type to preexclosure conditions. Stabilizing streambanks were refractured and began crumbling into the stream. Overhanging streambanks were eliminated. Vegetative cover and soil stability ratings decreased by 35% and 14% respectively to ratings similar to previous conditions. This habitat damage occurred within just six weeks of uncontrolled grazing use.

THE FUTURE

The BLM must prepare 212 environmental impact statements on 150 million acres of grazing lands with 19,000 miles of streams and adjoining riparian areas in the 11 western states. We have seen some of the current draft EIS's and they clearly reflect a "business as usual" attitude in relation to livestock grazing on riparian areas. Inadequately tested rest-rotation grazing systems are being relied on to increase the animal unit months (AUM) of grazing on riparian areas and, at the same time, improve and maintain desirable riparian conditions. At the Sparks, Nevada symposium, it was stated by fisheries biologists experienced with rest-rotation grazing, such as Dr. William Platts, of the U.S. Forest Service, that high livestock density at certain times may cause more damage to the riparian/stream habitats than former grazing systems. The findings of Duff (above) tend to corroborate Dr. Platts' statement. One or two years rest will not restore the vigor of woody vegetation, such as willows and shrubs, which are necessary to maintain stable streambanks and channels. It seems obvious to us that if the new BLM grazing proposals rely primarily on rest-rotation grazing systems, a continued downward trend will occur in the riparian vegetation with further reduction in fishery and wildlife habitat values.

Range managers and livestock interests have voiced the opinion that other public land use interests, primarily those of fisheries and wildlife, either want all livestock removed from public rangelands, or every mile of every stream on public lands fenced to exclude livestock. We do not believe that these are the goals of responsible fisheries and wildlife individuals or groups.

Fencing of streams is an effective means of restoring damaged riparian/stream ecosystems but is not a panacea for all of our range problems or the only possible management tool to protect valuable riparian/stream ecosystems. It also would be economically detrimental to permanently exclude livestock grazing from public lands or even from the highly productive and valuable riparian areas.

We suggest the following management options to help to resolve some of the areas of conflict concerning the use of riparian/stream ecosystems by domestic livestock.

1. Manage riparian areas for livestock grazing separately from upland range areas;
2. Fish and wildlife resources are of considerable economic value to the public sector. Some selected stream areas that are especially valuable to fisheries and wildlife resources should probably not be grazed. Other riparian areas should become fenced pastures to permit adequate control of livestock use.
3. Different classes of riparian habitats, such as forested, willow-shrub, and grass-forb types, should be identified and managed in accordance with their different degrees of resistence to livestock grazing.
4. When developing grazing management plans for riparian areas, the allocation of AUMs, season of grazing, and assignment of indicators to signal the time for removal of livestock should give reasonable consideration to protecting habitat features of value to the fisheries and wildlife resources of the area.
5. Fish and wildlife interests should not expect all riparian/stream habitats to be managed for maximum production of fish and wildlife. Some reasonable allocation of resource use and values are in order.
6. Livestock watering areas should be developed away from the riparian areas.
7. Spring areas should be fenced to protect their integrity with water for livestock

use piped outside of the fence.

8. Salt blocks should be located on upland range areas away from the riparian areas.

9. Cattle herding may be a viable option to protect certain riparian/stream habitat classes.

10. It was brought out at the Denver meeting that selective breeding of cattle that are less attracted to riparian areas than others may offer a partial solution to the problem.

11. The Bureau of Land Management and the U.S. Forest Service should fund an interagency, interdisciplinary study of acceptable, innovative grazing management procedures for riparian/stream ecosystems. Such a study should include representatives of all public land use interests including livestock and conservation interests. We believe that the public rangelands may be able to support present densities of AUMs on a sustained basis if they can be brought back to full forage production and adequate protection given to the highly productive riparian/stream ecosystems.

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Identification and Delineation of Riparian Wetlands: Problems and Proposed Solutions[1]

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and

James S. Wilson[4]

Abstract. Legislation authorizing the Corps of Engineers to regulate the discharge of dredged and fill material into Waters of the United States provided little guidance as to identification and delineation of areas subject to jurisdiction. This is especially true in determining the landward extent of wetlands. Corps research efforts in this area have led to the publication of a preliminary series of regional guides, identifying typical wetland plant communities found in the United States. Further development of these publications is continuing. Studies are also being conducted to provide Corps regulatory personnel with techniques for on-site determination of wetland boundaries. Preliminary research indicates that many wetlands can readily be separated from adjacent non-wetlands upon examination of the hydrologic regime and plant community structure.

PAPER NOT RELEASED BY CORPS OF ENGINEERS AT PRESS TIME. -Ed.

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[1]Presented at the National Symposium on Strategies For Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978. Paper not available at time of publication.

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Southwestern Wetlands - Their Classification and Characteristics[1]

David E. Brown[2]

Abstract.--A digitized, hierarchical classification system for biotic communities is presented along with a discussion of those wetland biomes occurring in the North American Southwest.

Several good wetland classifications have been promulgated during the past decade (e.g., Bayly 1967, Stewart and Kantrud 1971, Golet and Larson 1974, Ray 1975, Zoltai et al. 1975, Millar 1976 and especially, Cowardin et al. 1977). These classifications all employ a number of chemical, geologic and geographic modifiers as well as physiognomic and structural criteria. Unfortunately most of them do not emphasize the importance of evolutionary origin and regional adaptation on ecosystems and their plant <u>and</u> animal components (=biomes). Also, all are more or less regional in scope; none are universal. This has resulted in some resistance by biologists and others concerned with wildlife habitat identification, inventory, stratification, acquisition and preservation.

We have developed a hierarchical classification *system* for the world's biotic communities (Brown and Lowe 1973, 1974a, 1974b; Brown and Lowe and Pase 1977). The taxonomic nomenclature of this system is based on those factors most important in the evolution of origin, structure and composition on all ecosystems, both wetland and terrestrial. The digitation of hierarchy makes the system computer-compatible. Furthermore, it allows for flexibility in the inventory of those complex communities where intensive levels of mapping are impractical or needlessly time consuming.

An important advantage of a hierarchical system based on biotic criteria is the meaningful assignment of plant and animal habitats. This classsification not only recognizes plant components within an assigned ecological distribution, it tells the reader which wildlife species could be expected to be present. As an example the occurrence of nesting wood ducks (*Aix sponsa*) is expected in certain temperate swampforests and riparian forests, as opposed to tropical-subtropical swampforests expected in North America to be the nesting habitat of black-bellied whistling ducks (*Dendrocygna autumnalis*).

Our fourth level (biome) examples for North America are representative and are presented to illustrate the reality, adaptability and use of the classification system; they are not meant to be either a definitive or final classification. Examples of the use of the system to the fifth (series) and sixth (association) levels are given here only for those wetland biomes located wholly or partially within the North American Southwest (Fig. 1).

Incorporated in the classification are contributions of plant geographers, zoogeographers, wildlife biologists, and ecologists, all of which pertain to and are in general usage in the "Southwest" (e.g., Merriam 1890, Weislander 1935, Morris 1935, Nichol 1937, Tharp 1939, Gentry 1942, Muller 1947, Munz and Keck 1949, 1950; Gould 1951, Shreve 1942, 1951, Castetter 1956, Lowe 1964, Bradley and Deacon 1965, Flores et al. 1971, Brown 1973, Barbour and Major 1977 and Kuchler 1977.

[1]Paper presented at the National Riparian Ecosystems Symposium, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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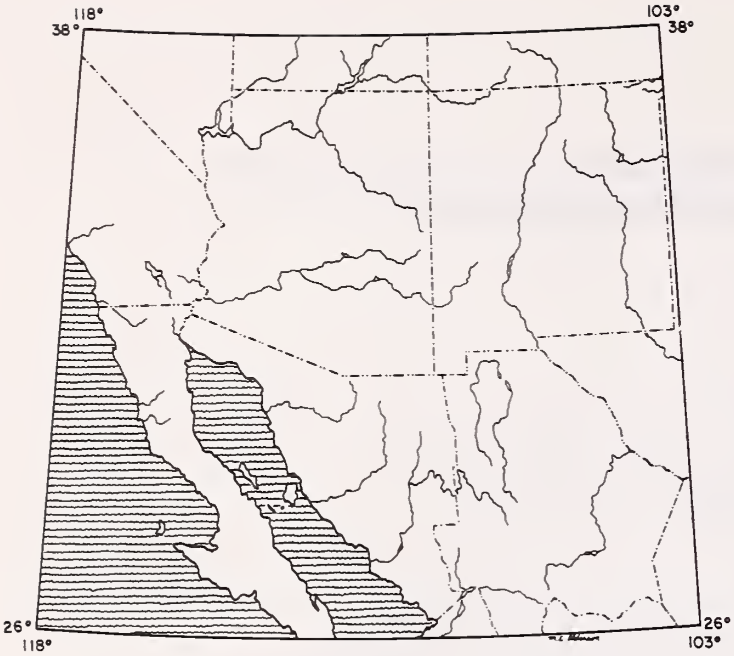

Fig. 1.-- The "American Southwest" is commonly considered as the states of Arizona and New Mexico. However, any delineation of a natural Southwest Region would have to include the Mexican half, the states of Sonora and Chihuahua. The inclusion of coastal southern California and Baja California is based on biotic criteria as well as on historical, social, and political convenience. Similarly, southeastern California, southern Nevada, southern Utah, southwest Colorado, west Texas, and western Coahuila are included.

A DIGITIZED HIERARCHY OF THE WORLD'S NATURAL ECOSYSTEMS

Where:
1,000=Biogeographic (Continental) Realm
1,100=Vegetation
1,110=Formation-type
1,111=Climatic (Thermal) Zone
1,111.1=Regional Formation (Biome)
1,111.11=Series (Community of generic dominants)
1,111.111=Association (Community of specific dominants)
1,111.1111=Composition-structure-phase

The number preceding the comma (e.g., 1,000) refers to the world's <u>biogeographic realms</u> (see Table 1). Origin and evolutionary history are here recognized as being of primary importance in the determination and classification of natural ecosystems. The mapable reality of the world's biogeographic realms is, of course, interpretive in part, for it is dependent on the criteria used. In those regions where the components of one realm merge gradually with those of another and the assignment of biogeographic origin is difficult, we include such transitional areas (wide ecotones) in both realms. The following seven realms are adapted from Wallace (1876), see also Hesse et al. (1937), Darlington (1957), Dansereau (1957), Walter (1973), I. U. C. N. (1974), Delaubenfels (1975), Cox et al. (1976):

1000 Nearctic: Continental North America exclusive of the tropics and most highland areas south of the Tropic of Cancer. We include those tropic-subtropic regions in and adjacent to the North American Southwest and the Caribbean.

2000 Palaearctic: Eurasia exclusive of the tropics. Africa north of the Sahel.

3000 Neotropical and Antarctican: Continental South America, Central America and most of Mexico south of Tropic of Cancer. Antarctic.

4000 Oriental: Southeast Asia, the Indian subcontinent. The Phillipines, Indonesia, etc.

5000 Ethiopian: Africa south of the Sahara, Malagasy and parts of the Arabian peninsula.

6000 Australian: Australia and Tasmania.

7000 Oceanic: Oceanic islands possessing a high degree of endemism.

<u>First level</u>.--<u>The first digit after the comma</u> (e.g. 1,<u>1</u>00) refers to vegetation, the structural and therefore measurable reality of ecosystems. Included are all potential and/or existing plant communities that are presumed to be established naturally under existing climate and the cessation of artificially disruptive (=man caused) influences (Table 1).

Table 1. Summary for the Natural Vegetation of the World to the First Digit Level.

Biogeographic Realm		1 Upland Vegetation	2 Wetland Vegetation
1,000.	Nearctic	1,100.	1,200.
2,000.	Palaearctic	2,100.	2,200.
3,000.	Neotropical-Antarctican	3,100.	3,200.
4,000.	Oriental	4,100.	4,200.
5,000.	Ethiopian	5,100.	5,200.
6,000.	Australian	6,100.	6,200.
7,000.	Oceanic	7,100.	7,200.

All existing and potential natural vegetation (PNV) is classified as belonging to Uplands (1,<u>1</u>00) or Wetlands (1,<u>2</u>00) as in

Table 2. Summary for the Natural UPLAND Vegetation of the World to the Second Level (Formation-Type).

Biogeographic Realm	Formation Type: 1. Tundra	2. Forest	3. Scrub-land	4. Grass-land	5. Desert-land	6. Nonvegetated
1,000 Nearctic	1,110	1,120	1,130	1,140	1,150	1,160
2,000 Palaearctic	2,110	2,120	2,130	2,140	2,150	2,160
3,000 Neotropical-Antarctican	3,110	3,120	3,130	3,140	3,150	3,160
4,000 Oriental	4,110	4,120	4,130	4,140	4,150	4,160
5,000 Ethiopian	5,110	5,120	5,130	5,140	5,150	5,160
6,000 Australian	6,110	6,120	6,130	6,140	6,150	6,160
7,000 Oceanic	7,110	7,120	7,130	7,140	7,150	7,160

Table 1, or cultivated lands (1,300, 1,400). The important adaptation inherent in plants and animals of terrestrial (upland) ecosystems as opposed to hydric or aquatic (wetland) ecosystems is recognized by this dichotomy (see also Martin et al. 1953 and Ray 1975). Discussed here, wetlands include those periodically, seasonally or continually submerged ecosystems populated by species and/or life forms different from the immediately adjacent (upland) climax vegetation; the maintenance of which is dependent on conditions more mesic than provided by the immediate precipitation. Certain ecosystems having both upland and wetland characteristics and components (e.g., riparian forests) could be properly considered as belonging to both divisions. They are presented here as wetlands (1,200).

Second level--Second digit after the comma (e.g. 1,110) refers to one of the following recognized ecological formations, which on a worldwide basis are the formation-types ("biome types") (Tables 2 and 3). On continents, these are referred to as formations which are vegetative responses (functions) to integrated environmental factors, most importantly avail-

Table 3. Summary for the Natural WETLAND Vegetation of the World to the Second Level (Formation-Type).

Biogeographic Realm	Formation Type: 1. Wet Tundra	2. Forest[1/]	3. Swamp-scrub	4. Marsh-land	5. Strand	6. Submergent
1,000 Nearctic	1,210	1,220	1,230	1,240	1,250	1,260
2,000 Palaearctic	2,210	2,220	2,230	2,240	2,250	2,260
3,000 Neotropical-Antarctican	3,210	3,220	3,230	3,240	3,250	3,260
4,000 Oriental	4,210	4,220	4,230	4,240	4,250	4,260
5,000 Ethiopian	5,210	5,220	5,230	5,240	5,250	5,260
6,000 Australian	6,210	6,220	6,230	6,240	6,250	6,260
7,000 Oceanic	7,210	7,220	7,230	7,240	7,250	7,260

1/ Swampforests, bog-forests and riparian forests.

able plant moisture.

UPLAND FORMATIONS

Tundra[1/]: Communities existing in an environment so cold that moisture is unavailable during most of the year, precluding the establishment of trees, and in which the maximum development is perennial herbaceous plants, shrubs, lichens and mosses, with grasses poorly represented or at least not dominant.

Forest and Woodland:

Forest: Communities comprised principally of trees potentially over 35 feet in height, and frequently characterized by closed and/or multilayered canopies.

Woodland: Communities dominated by trees with a mean potential height usually under 35 feet the canopy of which is usually open (sometimes very open)[2] or interupted and singularly layered.

Scrubland: Communities dominated by sclerophyll or microphyll shrubs and/or multi-stemmed trees, generally not exceeding 35 feet in height and usually presenting a closed physiognomy, or if open, interspaced with other perennial vegetation.

Grassland: Communities dominated actually or potentially by grasses and/or other herbaceous plants.

Desertland: Communities in an arid environment (usually less than 12 inches precipitation per annum) in which plants are separated by significant areas devoid of perennial vegetation.

[1]The holistic integrity of a "Tundra" formation is not without serious question. Treated here, tundra may also be composed of grasslands, scrublands, marshlands (wet tundra), and desertlands in an Arctic-Boreal climatic zone (Billings and Mooney 1968 Billings 1973).

[2]The "savanna" formation (Dyksterhuis 1957 and others) is here recognized as an ecotone between woodland and grassland. Those homogeneous areas in which the crowns of trees normally cover less than approximately 15 percent of the ground space are classified as grasslands where grasses are actually or potentially dominant (=savanna-grassland). Mosaics of grasslands and smaller or larger stands of trees and shrubs are "parklands"and are composed of two or more ecologically distinct plant formations (Walter 1973).

WETLAND FORMATIONS

Wet Tundra[1/]: Wetland communities existing in an environment so cold that available plant moisture is unavailable during most of the year, precluding the establishment of trees and all but a low herbaceous plant structure in a hydric matrix.

Swampforest; riparian forest: Wetland communities possessing an overstory of trees potentially over 35 feet in height, and frequently characterized by closed and/or multilayered canopies.

Swampscrub; riparian scrub: Wetland communities dominated by short trees and/or woody shrubs, generally under 35 feet in height and often presenting a closed physiognomy.

Marshland: Wetland communities, in which the principal plant components are herbaceous emergents which normally have their basal portions annually, periodically, or continually submerged.

Strand: Beach and river channel communities subject to infrequent but periodic submerion, wind driven waves and/or spray. Plants are separated by significant areas devoid of perennial vegetation.[3]

Submergents: Aquatic communities comprised entirely or almost entirely of plants mostly submerged or lacking emergent structures.

Some upland and wetland areas are essentially without vegetation or are sparingly populated by simple organisms, e.g., dunes, lava flows, playas, sinks, etc. For purposes of classification these areas could be considered as belonging to a nonvegetated formation-type. (Tables 2 and 3).

Third level.--Third digit beyond the comma (e.g., 1,111) refers to one of four world climatic zones (cf. Walter 1973: Ray 1975) in which temperature minima remain a major evolutionary control of and within the zonation and formation-types (Table 4 and 5).

[3]Strands can properly be considered as the wetland equivalent of desertland because of the harsh physical environment and resulting landscape physiognomy. While occurring in the usual sense on beaches and other seacoast habitats, freshwater strands also occur in river channels, along lake margins and below reservoir high water lines.

Table 4. Summary for the Natural UPLAND Vegetation of Nearctic and Adjacent Neotropical North America to the Third Level

Formation	1. Arctic Boreal	2. Cold Temperate	3. Warm Temperate	4. Subtropical Tropical
	Climatic (Thermal) Zone			
1,110 Tundra	1,111			
1,120 Forest & Woodland	1,121	1,122	1,123	1,124
1,130 Scrubland	1,131	1,132	1,133	1,134
1,140 Grassland	1,141	1,142	1,143	1,144
1,150 Desertland	1,151	1,152	1,153	1,154
1,160 Nonvegetated	1,161	1,162	1,163	1,164

Table 5. Summary for the Natural WETLAND Vegetation of Nearctic and Adjacent Neotropical North America to the Third Level

Formation	1. Arctic Boreal	2. Cold Temperate	3. Warm Temperate	4. Subtropical Tropical
	Climatic (Thermal) Zone			
1,210 Wet Tundra	1,211			
1,220 Forest[1/]	1,221	1,222	1,223	1,224
1,230 Swampscrub	1,231	1,232	1,233	1,234
1,240 Marshland	1,241	1,242	1,243	1,244
1,250 Strand	1,251	1,252	1,253	1,254
1,260 Submergent	1,261	1,262	1,263	1,264

[1/] Swampforests, bog-forests and riparian forests.

All four of these broad climatic zones are found in North America and the "Southwest".

Arctic-Boreal (Antarctic-Austreal): Characterized by lengthy periods of freezing temperatures, with growing season of short duration (generally less than 100-150 days), occasionally interrupted by nights of below freezing temperatures.

Cold Temperate: Freezing temperatures of short duration although of frequent occurrence during winter months. Potential growing season generally of from 100 to 200 days and confined to spring and summer when freezing temperatures are infrequent or absent.

Warm Temperate: Freezing temperatures of short duration but generally occurring every year during winter months. Potential growing season over 200 days with an average of less than 125-150 days being subject to temperatures lower than 0°C or chilling fogs.

Tropical-Subtropical: Infrequent or no 24-hour periods of freezing temperatures, chilling fogs or wind.

<u>Fourth level</u>.--(e.g., 1,111.<u>1</u>) refers to a sub-continental unit that is a <u>major biotic community</u> (=biome). These biomes are characterized by a distinctive evolutionary history--within a formation--and are centered in but not necessarily restricted to a biogeographic region or province possessing a particular precipitation pattern or other climatic regime (see e.g., Pitelka 1941, Dice 1943, Odum 1972, Dasman 1976, Franklin 1977). It is this and the fifth

levels that have provided the most successful and useful mapping of states, provinces and continents (e.g. Shantz and Zon 1924, Bruner 1931, Shreve 1951, Kuchler 1964, Franklin and Dryness 1973.

Biogeographic provinces and biomes are also the bases for the biosphere reserve program in the United States and elsewhere (I.U.C.N. 1974; Franklin 1977). A partial summary of the biotic communities for Nearctic and adjacent Neotropical America is given in Tables 6 and 7.

Fifth level.--(e.g., 1,111.11) provides the principal plant-animal communities within the biomes, recognized and distinguished primarily on distinctive climax plant dominants (=series). These series sometimes referred to as cover-types (e.g., Society of American Foresters 1962 or vegetation types (Flores et al. 1971) are each composed of one of more biotic associations characterized by shared climax dominants--within the same formation, zone, and biome (Oosting 1950, Lowe 1964, Franklin and Dryness 1973, Pfister et al. 1977). For example, the ponderosa pine series within Rocky Mountain montane conifer forest would include all those Rocky Mountain forest associations in which *Pinus ponderosa* was a dominant component. The diversity of tropical and sub-tropical climax dominants is of course often inherently more complex than in boreal and temperate communities.

It should be pointed out that some plants are highly facultative and the same species may be a dominant in more than one formation-type. As an extreme example, mesquite (*Prosopis juliflora*) may be the dominant life-form in certain woodland, scrubland, desertland, and even forest and disclimax grassland formations. The distribution of some plant dominants also spans more than one climatic zone (e.g., mesquite, cresote (*Larrea divaricata*) and the introduced *Tamarix*). The plant and animal associates of these dominants usually differ when passing from one formation-type or climatic zone to another, however. Numerous generic dominants and some species are shared also by more than one biome, e.g., *Populus*, *Salix*, *Pinus*, *Quercus*, *Larrea*, etc. Closer investigation usually reveals that biomes do not normally share the same speciation within genera and those that do may exibit major genetic differences.[5] For these reasons the determination of fifth and sixth level communities will require interpretive revision and modification of the classification as field investigations accumulate. Some of the more prevalent and commonly recognized wetland series in the Southwest are presented in Table 7 under their appropriate wetland biome.

[5] See e.g. Yang and Lowe 1968 and Yang 1970 for a discussion of chromosome races of *Larrea divaricata* in the various biomes of the Southwest's deserts.

Sixth level.--(e.g., 1,111.111) refers to distinctive plant associations (and associes) based on the occurrence of particular dominant species more or less local (or regional) in distribution and generally equivalent to habitat-types as outlined by R. and J. Daubenmire (1968), Layser (1974) and Pfister et al. (1977). While we demonstrate examples for certain associations within Southwestern wetland biomes, the enormous numbers of sets preclude presentation here for all treatments in Tables 6 and 7. These may be added at length for regional studies with a,b,c, sets.

Seventh level.--(e.g., 1,111.1111) accomodates detailed measurement and assessment(s) of quantitative structure, composition, density and other numerical determinations for dominants, understories and other associated species. Implementation of this level in the system is designed for particular intensive studies for limited areas (see e.g., Dick-Peddie and Moir 1970).

Table 6. Taxonomy of UPLAND Biotic Communities of Nearctic and Adjacent Neotropical North America.

1,100 Nearctic Upland Vegetation
- 1,110 Tundra Formation
  - 1,111 Arctic Tundras
    - 1,111.1 Polar (High Arctic) Tundra
    - 1,111.2 Alaskan (Low Arctic) Coastal Tundra
    - 1,111.3 Canadian (Barren Ground = Low Arctic) Tundra
    - 1,111.4 Arctic Alpine Tundra
    - 1,111.5[1] Rocky Mountain Alpine Tundra
    - 111.6 Sierran-Cascade Alpine Tundra
    - 111.7 Adirondack-Appalachian Alpine Tundra

120 Forest and Woodland Formation
- 121 Boreal Forests and Woodlands
  - 121.1 Canadian Subarctic Conifer Forest and Woodland (North American Tiaga)
  - 121.2 Appalachian Subalpine Conifer Forest
  - 121.3 Rocky Mountain Subalpine Conifer Forest and Woodland[2]
  - 121.4 Sierran-Cascade Subalpine Conifer Forest
  - 121.5 Madrean Subalpine Conifer Forest

[1] The first "1" (in front of comma and representing the Nearctic Realm) is understood, and dropped for tabular convenience only, from this point onward.

[2] Further consideration may warrant separation of this biotic community into Rocky Mountain and Great Basin units.

122 Cold Temperate Forests and Woodlands
- 122.1 Northeastern Deciduous Forest
- 122.2 Pacific Coastal (Oregonian) Conifer Forest
- 122.3 Rocky Mountain (=Petran) Montane Conifer Forest
- 122.4 Great Basin Conifer Woodland
- 122.5 Sierran-Cascade Montane Conifer Forest
- 122.6 Madrean Montane Conifer Forest

123 Warm Temperate Forests and Woodlands
- 123.1 Southeastern Mixed Deciduous and Evergreen Forest
- 123.2 Californian Mixed Evergreen Forest
- 123.3 Californian Evergreen Woodland
- 123.4 Madrean Evergreen Forest and Woodland
- 123.5 Relict Conifer Forest and Woodland

124 Tropical-Subtropical Forests and Woodlands
- 124.1 Caribbean Montane Rain Forest
- 124.2 Caribbean Cloud Forest
- 124.3 Caribbean Evergreen Forest
- 124.4 Caribbean Deciduous Forest
- 124.5 Tamaulipan Deciduous Forest
- 124.6 Sinaloan Deciduous Forest

130 Scrubland Formation

131 Arctic-Boreal Scrublands
- 131.1 Alaskan (Low Arctic) Coastal Scrub
- 131.2 Canadian (Low Arctic, Barren Ground) Subpolar Scrub
- 131.3 Alaskan Alpine and Subalpine Scrub
- 131.4 Adirondack-Appalachian Alpine and Subalpine Scrub
- 131.5 Rocky Mountain Alpine and Subalpine Scrub
- 131.6 Sierran-Cascade Alpine Scrub

132 Cold Temperate Scrublands
- 132.1 Great Basin Montane Scrub
- 132.2 Sierran-Cascade Montane Scrub
- 132.3 Plains Deciduous Scrub

133 Warm Temperate Scrublands
- 133.1 Californian Coastalscrub
- 133.2 Californian Chaparral
- 133.3 Interior Chaparral
- 133.4 Southeastern Maritime Scrub

134 Tropical-Subtropical Scrublands
- 134.1 Caribbean Thornscrub
- 134.2 Tamaulipan Thornscrub
- 134.3 Sinaloan Thornscrub

140 Grassland Formation

141 Arctic-Boreal Grasslands
- 141.1 Alaskan (Low Arctic) Coastal Grassland
- 141.2 Canadian (Low Arctic) Grassland
- 141.3 Appalachian Subalpine (Balds) Grassland
- 141.4 Rocky Mountain Alpine and Subalpine Grassland
- 141.5 Sierran Cascade Alpine and Subalpine Grassland
- 141.6 Madrean Alpine and Subalpine Grassland

142 Cold Temperate Grasslands
- 142.1 Plains Grassland
- 142.2 Great Basin Shrub-Grassland
- 142.3 Pacific Coastal (Oregonian) Grassland
- 142.4 Rocky Mountain Montane Grassland
- 142.5 Sierran-Cascade Montane Grassland

143 Warm Temperate Grasslands
- 143.1 Chihuahuan Scrub-Grassland (Semidesert Grassland)
- 143.2 Californian Valley Grassland

144 Tropical-Subtropical Grasslands
- 144.1 Caribbean Savanna Grassland
- 144.2 Gulf Coastal (Tamaulipan) Grassland
- 144.3 Sonoran Savanna Grassland

150 Desertland Formation

151 Arctic-Boreal Desertlands
- 151.1 Polar Desertscrub

152 Cold Temperate Desertlands
- 152.1 Great Basin Desertscrub

153 Warm Temperate Desertlands
- 153.1 Mohave Desertscrub
- 153.2 Chihuahuan Desertscrub

154 Tropical-Subtropical Desertlands
- 154.1 Sonoran Desertscrub

Table 7. Taxonomy of WETLAND Biotic Communities (Fourth Level) of Nearctic and Adjacent Neotropical North America with Some Community (Series) and Association Level Examples for the North American Southwest.

1,200 Nearctic Wetland Vegetation

1,210 Wet Tundra Formation
- 211.1 Polar (High Arctic) Wet Tundra[1]
- 211.2 Greenlandian Wet Tundra
- 211.3 Alaskan (Coastal) Wet Tundra
- 211.4 Canadian (Low Arctic) Wet Tundra

220 Forest Formation

221 Boreal Swamp and Riparian Forests
- 221.1 Canadian Swampforest

222 Cold Temperate Swamp and Riparian Forests
- 222.1 Northeastern Bog, Swamp and Riparian Forests
- 222.2 Plains and Great Basin Riparian Deciduous Forest
  - 222.21 Cottonwood-Willow Series*
    - 222.211 *Populus sargenti* Associations*
    - 222.212 *Populus sargenti-Salix amygdaloides* Associations*
    - 222.213 *Populus wislizeni* Associations*
    - 222.214 *Populus* spp.-*Salix* spp. Associations*
    - 222.215 *Salix exigua* Associations*
- 222.3 Rocky Mountain Riparian Deciduous Forest
  - 222.31 Cottonwood-Willow Series*
    - 222.311 *Populus angustifolia-Salix* spp. Associations*

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* One or more examples only are given for these levels.

[1] The first "1" (in front of comma and representing the Nearctic Realm) is understood, and dropped for tabular convenience only, from this point onward.

222.32 Mixed Broadleaf Series*
222.321 _Acer negundo-Populus angustifolia_-mixed deciduous Associations*
222.322 _Acer grandidentatum_ Associations*
222.4 Sierran-Cascade Riparian Deciduous Forest
222.41 Cottonwood-Willow Series*
222.411 _Populus trichocarpa-Salix spp._ Associations*
222.42 Mixed Broadleaf Series*
222.412 _Acer macrophyllum-Populus trichocarpa-Alnus rhombiflora_ mixed deciduous Associations*
223 Warm Temperate Swamp and Riparian Forests
223.1 Southeastern Swamp and Riparian Forest
223.2 Interior Southwestern Riparian Deciduous Forest and Woodland
223.21 Cottonwood-Willow Series*
223.221 _Populus fremonti-Salix spp._ Associations*
223.212 _Populus fremonti_ Associations*
223.213 _Populus wislizeni_ Associations*
223.214 _Populus acuminata_ Associations*
223.22 Mixed Broadleaf Series*
223.221 _Platanus wrightii-Fraxinus velutina-Populus fremonti_-mixed deciduous Associations*
223.222 _Platanus wrightii_ Associations*
223.223 _Fraxinus velutina_ Associations*
223.224 _Alnus oblongifolia_ Associations*
223.225 _Juglans major_ Associations*
223.3 Californian Riparian Deciduous Forest and Woodland
223.31 Cottonwood-Willow Series
223.311 _Populus spp.-Salix spp._ Associations*
233.32 Mixed Broadleaf Series
223.321 _Platanus racemosa_-mixed deciduous Associations*
223.322 _Alnus rhombifolia_ Associations*
224 Tropical-Subtropical Swamp, Riparian and Oasis Forests
224.1 Caribbean Freshwater Swamp and Riparian Forests
224.2 Caribbean Maritime Swampforest
224.3 Tamaulipan Freshwater Swamp and Riparian Forests
224.4 Sinaloan Interior Swamp and Riparian Forests
224.41 Mixed Evergreen Series*
224.411 _Ficus spp._-mixed evergreen and deciduous Associations*
224.412 _Taxodium mucronatum_ Associations*
224.413 _Populus sp._-mixed evergreen and deciduous Associations*
224.42 Palm Series*
224.421 _Sabal uresana_ Associations*

* Examples only

224.5 Sonoran Oasis Forest
224.51 Palm Series*
224.511 _Washingtonia filifera_ Associations*
224.512 _Washingtonia filifera-Populus fremonti_ Associations*
224.513 _Washingtonia filifera-Brahea armata_ Associations*
224.514 _Brahea armata_ Associations*
224.515 _Phoenix dactylifera-Washingtonia filifera_ Associations*
230 Swampscrub Formation
231 Arctic-Boreal Swampscrubs
231.1 Polar (High Arctic) Swampscrub
231.2 Greenlandian Swampscrub
231.3 Alaskan Swampscrub
231.4 Canadian Swampscrub
231.5 Adirondack-Appalachian Alpine and Subalpine Swamp and Riparian Scrub
231.6 Rocky Mountain Alpine & Subalpine Swamp and Riparian Scrub
231.61 Willow Series*
231.611 _Salix bebbiana_ Associations*
231.7 Sierran-Cascade Alpine & Subalpine Swamp and Riparian Scrub
231.71 Willow Series*
231.711 _Salix spp._ Associations*
232 Cold Temperate Swamp and Riparian Scrubs
232.1 Northeastern Deciduous Swampscrub
232.2 Plains and Great Basin Riparian Scrub
232.21 Willow Series*
232.211 _Salix spp._-mixed scrub Associations
232.22 Saltcedar Disclimax Series*
232.221 _Tamarix chinensis_ Associations*
232.3 Rocky Mountain Riparian Scrub
232.31 Willow-Dogwood Series*
232.311 _Salix spp._-mixed deciduous Associations*
232.4 Sierran-Cascade Riparian Scrub
232.41 Willow Series*
232.411 _Salix spp._ Associations
232.5 Pacific Coastal (Oregonian) Deciduous Swampscrub
233 Warm Temperate Riparian and Swamp Scrubs
233.1 Southeastern Mixed Deciduous and Evergreen Swampscrub
233.2 Interior Southwestern Swamp and Riparian Scrub
233.21 Mixed Narrowleaf Series*
233.211 _Cephalanthus occidentalis-Baccharis glutinosa_-mixed scrub Associations*
233.22 Saltcedar Disclimax Series*
233.221 _Tamarix chinensis_-mixed deciduous Associations*
233.3 Californian Deciduous Swamp and Riparian Scrub
233.31 Mixed Narrowleaf Series*
233.311 _Salix lasiolepis_ Associations*
234 Tropical-Subtropical Swampscrub
234.1 Caribbean Interior Swampscrub

* Examples only

234.2 Caribbean Maritime Swampscrub
234.3 Tamaulipan Interior Swampscrub
234.4 Tamaulipan Maritime Swampscrub
234.5 Sinaloan Interior Swamp and Riparian Scrub
234.51 Mixed Evergreen Series*
234.511 *Vallesia glabra*-*Baccharis glutinosa*-*Salix bonplandia* Assoc.*
234.6 Sinaloan Maritime Swampscrub
234.61 Mangrove Series*
234.611 *Avicennia nitida* Associations*
234.612 *Rhizophora mangle* Associations*
234.7 Sonoran Deciduous Swamp and Riparian Scrub
234.71 Mixed Scrub Series*
234.711 *Prosopis pubescens*-*Prosopis juliflora torreyana*-*Pluchea sericea* Associations*
234.72 Saltcedar Disclimax Series*
234.721 *Tamarix chinensis* Associations*
234.722 *Tamarix chinensis*-mixed scrub Associations*
240 Marshland Formation
241 Arctic-Boreal Marshlands
241.1 Polar (High Arctic) Marshland
241.2 Greenlandian Marshland
241.3 Alaskan Maritime (Coastal) Marshland
241.4 Canadian Interior Marshland
241.5 Canadian Maritime (Coastal) Marshland
241.6 Adirondack-Appalachian Alpine and Subalpine Marshland
241.7 Rocky Mountain Alpine and Subalpine Marshland
241.71 Rush Series*
241.711 *Juncus balticus* Associations*
241.72 Manna Grass Series*
241.721 *Glyceria borealis* Associations*
241.8 Sierran-Cascade Alpine and Subalpine Marshland
241.81 Rush Series*
241.811 *Juncus spp.* Associations*
242 Cold Temperate Marshlands
242.1 Northeastern Interior Marshland
242.2 Northeastern Maritime (Coastal) Marshland
242.3 Plains Interior Marshland
242.31 Rush Series*
242.311 *Juncus tenuis* Associations
242.32 Bur-reed Series*
242.321 *Sparganium angustifolium* Associations*
242.33 Cattail Series*
242.331 *Typha latifolia* Associations*
242.34 Bulrush Series*
242.341 *Scirpus validus* Associations*
242.4 Rocky Mountain Montane Marshland
242.41 Rush Series*
242.411 *Juncus saximontanus* Associations
242.5 Great Basin Interior Marshland
242.51 Rush Series*

* Examples only

242.511 *Juncus acutis* Associations*
242.52 Saltgrass Series*
242.521 *Distichlis stricta* Assoc.*
242.6 Sierran-Cascade Montane Marshlands
242.61 Rush Series*
242.611 *Juncus spp.* Associations*
242.7 Pacific Coastal (Oregonian) Interior Marshland
242.8 Pacific Coastal (Oregonian) Maritime Marshland
243 Warm Temperate Marshlands
243.1 Southeastern Interior Marshland
243.2 Southeastern Maritime Marshland
243.3 Chihuahuan Interior Marshland
243.31 Saltgrass Series*
243.311 *Distichlis stricta* Assoc.*
243.4 Mohavian Interior Marshland
243.41 Rush Series*
243.411 *Juncus cooperi* Associations*
243.42 Saltgrass Series
243.421 *Distichlis stricta* Assoc.*
243.5 Madrean Montane Marshland
243.51 Rush Series*
243.511 *Juncus mexicanus* Associations*
243.6 Californian Interior Marshland
243.61 Cattail Series*
243.611 *Typha latifolia* Associations*
243.612 *Typha domingensis* Assoc.*
243.7 Californian Maritime Marshland
243.71 Cordgrass Series*
243.711 *Spartina foliosa* Associations*
243.72 Glasswort Series*
243.712 *Salicornia virginica* Associations*
244 Tropical-Subtropical Marshland
244.1 Caribbean Interior Marshland
244.2 Caribbean Maritime Marshland
244.3 Tamaulipan Interior Marshland
244.4 Gulf Coast Maritime Marshland
244.5 Sinaloan Interior Marshland
244.51 Cattail Series*
244.511 *Typha domingensis* Associations*
244.6 Sinaloan Maritime Marshland
244.61 Glasswort Series
244.611 *Salicornia sp.* Associations*
244.7 Sonoran Interior Marshland
244.71 Cattail Series
244.711 *Typha domingensis* Associations*
244.72 Reed Series*
244.721 *Phragmites communis* Associations*
244.73 Bulrush Series*
244.731 *Scirpus americanus* Assoc.
244.74 Threesquare Series*
244.741 *Scirpus olneyi* Associations*
244.8 Sonoran Maritime Marshland
244.81 Saltgrass Series*
244.811 *Distichlis stricta* Associations*
244.82 Glasswort Series*
244.821 *Salicornia sp.* Associations*
250 Strand Formation
251 Arctic-Boreal Strands
251.1 Polar Maritime Strand
251.2 Greenlandian Strand

* Examples only

251.3 Alaskan Maritime Strand
251.4 Canadian Interior (Stream and Lake) Strand
251.5 Canadian Maritime Strand
251.6 Adirondack-Appalachian Alpine and Subalpine Stream and Lake Strand
251.7 Rocky Mountain Alpine and Subalpine Stream and Lake Strand**
251.8 Sierran Cascade Alpine and Subalpine Stream and Lake Strand**
252 Cold Temperate Strands
252.1 Northeastern Interior (Stream and Lake) Strand
252.2 Northeastern Maritime Strand
252.3 Plains Interior (Stream and Lake) Strand
252.31 Annual Series
252.311 Xanthium saccharatum-mixed annual Associations*
252.4 Rocky Mountain Interior Strand*
252.41 Annual Series**
252.5 Great Basin Interior Strand*
252.51 Annual Series**
252.6 Sierran-Cascade Interior Strand*
252.61 Annual Series**
252.7 Pacific Coastal (Oregonian) Interior Strand
252.8 Pacific Coastal (Oregonian) Maritime Strand
253 Warm Temperate Strands
253.1 Southeastern Interior Strand
253.2 Southeastern Maritime Strand
253.3 Chihuahuan Interior Strand
253.31 Annual Series*
253.311 Xanthium saccharatum Associations*
253.4 Mohavian Interior Strand
253.41 Annual Series*
253.411 Xanthium saccharatum Associations*
253.42 Mixed Scrub Series
253.412 Tamarix chinensis-mixed scrub Associations*
253.5 Madrean Interior Strand
253.51 Annual Series*
253.511 Mixed annual Associations*
253.6 Californian Interior Strand
253.61 Annual Series*
253.611 Nicotiana attentuata Associations*
253.7 Californian Maritime Strand
253.71 Mixed Scrub Series*
253.711 Abronia maritima-Atriplex leucophylla-Cakile maritima et al. Associations*

*Examples only

**Our incomplete knowledge of these biotic communities precludes presentation of representative fifth (series) and sixth level (association) examples.

253.72 Sea-grass Series*
253.721 Phyllospadix scouleri Associations*
253.73 Green Algae Series*
253.731 Ulva californica Associations*
253.74 Brown Algae Series*
253.741 Pelvetia fastigiata Associations*
253.75 Red-Algae Series*
253.751 Gigartina conaliculata Associations*
254 Tropical-Subtropical Strands
254.1 Caribbean Interior Strand
254.2 Caribbean Maritime Strand
254.3 Tamaulipan Interior Strand
254.4 Gulf Coast (Tamaulipan) Maritime Strand
254.5 Sinaloan Interior Strand*
254.51 Annual Series**
254.6 Sinaloan Maritime Strand**
254.61 Mixed Scrub Series*
254.7 Sonoran Interior Strand
254.71 Mixed Scrub Series*
254.711 Baccharis glutinosa-Solanum nodiflorum-Nicotiana spp. Rumex hymenocephalis et al. Associations*
254.72 Annual Series*
254.721 Amaranthus palmeri Associations*
254.8 Sonoran Maritime Strand
254.81 Mixed Scrub Series
254.811 Abronia maritima-Helianthus niveus-Jouvea pilosa et al. Associations*
260 Submergent Vegetation
261 Arctic-Boreal Submergents
261.1 Polar Marine Submergents
261.2 Greenlandian Inland Submergents
261.3 Alaskan Marine Submergents
261.4 Canadian Inland Submergents
261.5 Canadian Marine Submergents
261.6 Adirondack-Appalachian Alpine and Subalpine Submergents
261.7 Rocky Mountain Alpine and Subalpine Submergents
261.71 Pondweed Series*
261.711 Potamogeton natans Associations*
261.8 Sierran-Cascade Alpine and Subalpine Submergents
261.81 Pondweed Series*
261.811 Potamogeton alpinus Associations*
262 Cold Temperate Submergents
262.1 Northeastern Inland Submergents

*Examples only

**Our incomplete knowledge of these biotic communities precludes presentation of sixth level (association) examples.

262.2 Northeastern Marine Submergents
262.3 Plains Inland Submergents
262.31 Pondweed Series*
262.311 _Potamogeton foliosus_ Associations*
262.4 Rocky Mountain Montane Submergents
262.41 Pondweed Series*
262.411 _Potamogeton foliosus_ Associations*
262.5 Great Basin Inland Submergents
262.51 Pondweed Series*
262.511 _Potamogeton foliosus_ Associations*
262.6 Sierran Cascade Montane Submergents
262.61 Pondweed Series*
262.611 _Potamogeton pusillus_ Associations*
262.7 Pacific Coastal (Oregonian) Inland Submergents
262.8 Pacific Coastal (Oregonian) Marine Submergents
263 Warm Temperate Submergents
263.1 Southeastern Inland Submergents
263.2 Southeastern Marine Submergents
263.3 Chihuahuan Inland Submergents
263.31 Pondweed Series*
263.311 _Potamogeton pectinatus_ Associations*
263.4 Mohavian Inland Submergents
263.41 Pondweed Series*
263.411 _Potamogeton pectinatus_ Associations*
263.5 Madrean Inland Submergents
263.51 Pondweed Series*
263.511 _Potamogeton pectinatus_ Assoc.
263.6 Californian Inland Submergents
263.61 Pondweed Series*
263.611 _Potamogeton pectinatus_ Associations*
263.62 Milfoil Series
263.621 _Myriophyllum exalbescens_ Associations
263.7 Californian Marine Submergents
263.71 Ruppia Series*
263.711 _Ruppia maritima_ Associations*
263.72 Eelgrass Series*
263.721 _Zostera marina_ Associations
263.73 Giant Kelp Series*
263.731 _Macrocystis pyrifera_ Associations*
263.74 Feather-boa kelp Series*
263.741 _Egregia laevigata_ Associations*
263.75 Southern Sea Palm Series*
263.751 _Eisenia arborea_ Associations*
264 Tropical-Subtropical Submergents
264.1 Caribbean Inland Submergents
264.2 Caribbean Marine Submergents
264.3 Tamaulipan Inland Submergents
264.4 Gulf Coastal Marine Submergents
264.5 Sinaloan Inland Submergents

* Examples only

264.51 Pondweed Series**
264.6 Sinaloan Marine Submergents*
264.61 Phytoplankton Series**
264.7 Sonoran Inland Submergents**
264.71 Pondweed Series
264.711 _Potamogeton pectinatus_ Associations*
264.72 Milfoil Series*
264.721 _Myriophyllum brasiliense_ Associations*
264.8 Sonoran Marine Submergents
264.81 Ruppia Series*
264.811 _Ruppia maritima_ Associations*
264.82 Eelgrass Series*
264.821 _Zostera marina_ Associations*

*Examples only

**Our incomplete knowledge of these biotic communities precludes presentation of sixth level (association) examples.

As defined previously, wetlands are periodically, seasonally or continually submerged lands populated by species and/or life forms different from the immediately adjacent vegetation, maintained and dependent on conditions more mesic than provided by the immediate precipitation. Such conditions occur in or adjacent to drainageways and their floodplains (riparian), on poorly drained lands, along seacoasts and in other hydric and aquatic situations, _i.e._ springs, ponds, lake margins, etc. The various wetland and riparian communities present may be represented as forest or woodland, scrubland, marshland, or strand--or be composed largely or entirely of submergent vegetation. Although, on occasion, these formations are often quite distinct, they are also often highly integrated or occur as intermittent stands within other communities. Although the formation-classes represented may frequently be complex, the number of dominants may be surprisingly few. Also, the formations encountered are often successional due to disturbances brought on by periodic flooding and inundation. The communities and associations moreover are dynamic, subject to frequent change, replacement, and succession. For these reasons, and because of their extremely limited area in the Southwest, riparian and other wetland biotic communities are either not differentiated or not shown on vegetation maps. These biomes possess an important and biological interest entirely disproportionate to their limited geographic area, however.

The Southwest's major rivers--the Colorado, Gila, Salt, Rio Grande, Pecos, Conchos, Sonora, Yaqui, Mayo, Santa Ana and San Gabriel--have been dammed for many years; their flows have

been altered and diverted and their once perennial lower regions dessicated. In fact, the Southwest's greatest river--the Colorado--with the exception of a few important reaches, has been reduced to a series of reservoirs connected by canal-like channels. These regulated rivers now have much of their former nutrient load trapped upstream in reservoirs. Furthermore, temperature and discharge regimes are now unsuitable for a native aquatic biota adapted to warmer waters and spring flooding; their endemic fish fauna has been largely destroyed and replaced by introductions (see e.g. Miller 1961, Minckley 1973). Some of the lesser rivers and streams are as yet unregulated however, and the upper Gila, Verde, Salt, Conchos and Mayo as well as the San Pedro, Galivan, San Miguel, and other rivers along with many tributary streams still possess native aquatic faunas, although impacted by introduced species.

Prior to 1880, alluvial river bottoms at lower elevations (<3500 ft.) were much wetter and less well drained than at present. Streams were commonly characterized by boggy margins, marshy sloughs and backwaters which were of great annoyance to early travelers and a health hazard to the 19th Century military posts (Hastings 1959). Stream channels were typically shallow and braided with more meanders and oxbows than at present. Beaver activity was everywhere evident and marshy conditions generally prevailed (Davis 1973). The well known but poorly understood cycle of arroyo-cutting initiated in the 1880's and 1890's (Bryan 1925, 1928; Cooke and Reeves 1976, Leopold 1976) coupled with deliberate river channelization, streamflow impoundment and diversion and ground water pumping has caused these riverine marshlands to become an almost extinct landscape feature in the Southwest.

Natural lakes and ponds are rare in the Southwest owing to the lack of recent glaciation, general aridity, high evaporation and siltation rates, and the steep gradient of much of the topography. Far more numerous are artificial reservoirs (presas), farm ponds (estanques) and the numerous earthen cattle "tanks" (represos or charcos) of various degrees of permanence. With the exception of some high elevation lakes in southwest Colorado, most natural lakes (lagunas) are sinks, either enclosed basins (bolsons) or volcanic calderas subject to great fluctuations in water levels and therefore more or less marshy and seasonal. These bodies usually do not have perennial inflow and often no outlet--water leaving the system by evaporation and downward percolation if the lake is perched above the groundwater table. Such lakes are often saline and although heavily used by waterfowl, shore and wading birds, provide little habitat for fish. Some larger and well known examples are Lake Elsinore in California, Mormon Lake in Arizona, Buford Lake (Stinking Lake) in New Mexico and the Lagunas Guzman, Babicora, Bustillos and de los Mexicanos--all in Chihuahua. The natural lakes which provide the most dependable aquatic habitats are usually those at higher elevations with the attendent increased precipitation and reduced evaporation (e.g. Mormon Lake elevation ca. 7000 ft.) or those few depressions such as Laguna Prieta in northwest Sonora that intersect groundwater tables. Normally dry closed basin lakes are called playas and, although considered characteristic landscape features within the Chihuahuan Biotic Province, they are in fact found in all four North American deserts and indeed throughout the Southwest. Two of the largest of these--the Salton Sea in California and Laguna Salada in Baja California Norte--have been, or are in the process of being, transformed into large permanent bodies of water through the diversion of Colorado River water.[1]

The coastline beaches of Baja California, southern California and Sonora with their adjacent marine environments provide the richest and most extensive as well as spectacular wetland and aquatic habitats in the Southwest. In addition to strand vegetation on rock cliff; rubble beach, mud and sand, are the tide marshes; now greatly reduced but once occupying most estuaries (esteros). Of great importance but outside the scope of this discussion, are the offshore submergent communities--as yet unclassified and only partially described. Here "forests" of kelp, and eel grass "meadows" and many less structurally distinct underseascapes have a flora and fauna known only to a relative few. The life histories and ecological relationships of even many of the most important species are as yet poorly understood and open to discovery; e.g. the recent observations reported by Felger et al. (1976) regarding the overwintering of green sea-turtles (*Chelonia mydas*) in the Gulf of California. This is surprising considering the economic, scientific and recreational importance of these marine resources both in the United States and Mexico.

It should not go unnoticed that our estuary, riparian and other wetland communities are continuing to be rapidly reduced with the decline of streamflows and watertables. Furthermore, the increasing and seemingly insatiable demands placed on all the arid Southwest's water resources make the future outlook for many of the remaining communities tenuous at best. Certainly the loss--just within one generation--of numerous unique riparian and marshland ecosystems, ranging in size from small spring-fed marshes to the recently extensive backwaters

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[1]For a most interesting account of the filling of the Salton Sea, the reader is referred to G. Sykes, *The Colorado Delta*.

of the lower Colorado River and its delta, is an ominous portent. Powerful economic incentives and a general public insensitivity insure the continued reduction of our Southwestern wetlands and their attendent biotas.

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Management of Floodplain Wetlands and Other Riparian Ecosystems

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Interaction of Water Management and Riparian Ecosystems: Attitudes, Practices, and Effects[1]

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Under its broad mission of planning, developing, and managing water and related land resource projects which supply water for agriculture, domestic, and industrial use in the 17 western states, the Bureau of Reclamation also fulfills the mission of preserving or mitigating riparian habitat.

The Bureau of Reclamation has the general mission to plan, design, construct, operate, and maintain works for conservation, storage, diversion, and development of waters for the reclamation of arid and semiarid lands in 17 Western States. The basic objectives of the Federal Reclamation program are to assist the States, local governments, and other Federal agencies in stabilizing and stimulating local and regional economies, enhancing and protecting the environment, and improving the quality of life through development of water and related land resources throughout the 17 contiguous Western States. To fulfill this mission and meet these objectives, the Bureau operates and maintains a variety of projects which deliver municipal and industrial water supplies, generate hydroelectric power, provide irrigation water, improve water quality, conserve and develop fish, wildlife and other environmental values, and provide outdoor recreation, flood control, and river regulation.

This is a broad mission and we accomplish it through a wide range of activities. However, most relevant for our discussion today is the fish and wildlife objective. This objective requires the full recognition that fish and wildlife resources are as important as other resources. The significance of riparian vegetation to Bureau programs is related to the objective of conserving and developing fish and wildlife resources. Much of the impetus behind the Bureau's present environmental awareness was provided by the National Environmental Policy Act of 1969. Reclamation has focused on the requirements of this Act and particularly toward those which promote the concept of man and nature existing together in productive harmony.

Riparian vegetation, or that vegetation adjacent to a water supply such as a riverbank, lake, or pond, is encompassed by the Fish and Wildlife Coordination Act of 1958 which states that "wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs." The Act defined wildlife as including the habitat which supports it. Bureau planning is guided by the Principles and Standards as promulgated by the Water Resources Council. Our planning, therefore, should emphasize environmental quality as much as economic development. An essential part of environmental quality is the continued maintenance of wildlife resources including the riparian vegetation which so largely nurtures important species in the Southwest.

Compared to the Southeast, the West is by and large arid. Water supplies are largely dependent upon the meager rainfall and the snow that falls in the mountains. At the lower elevations, the richest vegetation is riparian. However, it is not nearly

[1] Paper presented at the symposium, Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11 - 13, 1978.

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as broad or as dense as that found in the East.

When considering riparian vegetation in the West, several important points have to be kept in mind. One is that the West's predominant water law system is based on prior appropriation, which means that the first in time have first right to use of the water. The second is that, due to the limited availability of water, it is often overappropriated; therefore, little water is left to devote to other than traditional and historic uses. What this means in practice is that to allocate water to any use, including the expansion of riparian vegetation, requires a water right, and new water rights are scarce. A third thing to keep in mind is that water rights are administered under State water laws. Hence water rights are a State matter and are not under the control of the Federal government.

There are only a few water rights in the West devoted strictly to the maintenance of riparian vegetation. For instance, on the lower Colorado River, the Havasu, Imperial, and Cibola National Wildlife Refuges have limited water rights, but these are low in priority. Most riparian vegetation along western streams is supported by water lost naturally from the stream as it runs through its course. Although no water right is adjudicated, nature has arranged that the first use of water is by vegetation. To speak candidly, the Bureau, along with other agencies, has been a child of its times. In the days of emphasis on dam building and river taming, there were other priorities which took precedence. Power production and agricultural expansion were seen as vital to fuel our nation's growth, and flood control was essential to protect that growth. So water was not set aside for the maintenance of riparian vegetation. We now recognize that riparian vegetation is a valuable resource, essential to the maintenance of a healthy and pleasing environment for humans as well as fish and wildlife. Yet the West has little water devoted to enhancing riparian vegetation.

Riparian vegetation has declined steadily over the years. Taking the cottonwood as an example, we can see the rate of decline. For instance, in a paper called "A Riparian Case History: The Colorado River," Drs. Ohmart, Deason, and Burke stated that "Cottonwood communities have declined from high abundance (5,000 acres plus) along the lower Colorado River in the 1600's to scattered groves containing a few mature individuals today." They went on to say that, if one considered pure cottonwood communities, there would be less than 500 acres left today.

The decline of native riparian vegetation in the West has been complicated by the introduction of exotic species of plants, especially other phreatophytes. These phreatophytes have shown an explosive growth rate, moving not only into vacant areas but also those areas occupied by native species. These species seem to compete far more successfully for the little water available than the native species such as cottonwoods, mesquites, and willows. So not only has much of the native riparian vegetation been sacrificed for agriculture, flood control, power production, and recreational and urban development, but much of it is still being lost due to the proliferation of non-native species like saltcedar. Saltcedar, unfortunately, has less wildlife value than native species such as cottonwood, mesquite, and willow, and, what is worse, saltcedar seems to use far more water than these native species.

Preserving riparian vegetation has therefore become a management problem. However, every problem presents a challenge. The maintenance and enhancement of riparian vegetation in the West is just such a challenge. I would like to discuss what the Bureau of Reclamation is doing to respond to that challenge using the Lower Colorado Region as an example.

This Region is headquartered in Boulder City, Nevada and is under the direction of Manuel Lopez, Jr. It extends from below Glen Canyon Dam in northern Arizona to the Mexican border near Yuma, Arizona. It comprises the lower Colorado River drainage basin in which the Colorado River travels a distance of almost 700 miles. The major project along the river is Hoover Dam and Lake Mead located at Boulder City, Nevada. Hoover Dam and the subsidiary dams and reservoirs have the priorities of providing flood control, furnishing irrigation and domestic water, and producing power. The lower Colorado River and its tributaries support a thriving agricultural, industrial, and metropolitan growth supporting the needs of about 15 million people.

The riparian vegetation program of the Lower Colorado Region has evolved by phases. The first step was a research phase which, by the way, is still going on. The Lower Colorado Region, in response to the general environmental awareness sparked by NEPA, recognized the problem of declining riparian vegetation in the early 1970's. They realized that the first step in any successful

management program was to accurately determine the types of riparian vegetation in the basin and the types of wildlife it supported. This knowledge could then be used as the baseline for developing concepts and programs to maintain and promote a healthy riparian habitat.

Initially planned as a 3-year effort, this baseline study has been extended several times and is now in its sixth year. It should be completed in 1980. Under contract with Arizona State University, researchers have collected data on (1) plant species composition and density, (2) the macro-and micro-climatic conditions along with physical and chemical characteristics of the soil, (3) the relative abundance, distribution, and diversity of birds, mammals, reptiles, and amphibians, and (4) types of habitat modifications beneficial or detrimental to wildlife. Biological models have also been developed which will predict the wildlife changes that will occur with controlled modifications of the plant communities. I would like to give you some idea of the size of our studies. We are using 150 transects. Each transect is a 1/2 to 1 mile long, so we are studying nearly 100 miles of the river. Transects are censused for birds two or three times monthly and censused for small mammals every 2 to 3 months. We read about 12,000 acres monthly, and have been doing so for over 4 years, so you get some idea of the amount of data we are collecting.

The second step in the riparian vegetation program in the Lower Colorado Region is the experimental application of some of the management concepts at selected spots along the river. The undeveloped areas of the flood plain of the lower Colorado river are now largely infested with saltcedar, which was introduced before the turn of the century and has since spread throughout the Southwest. Our experiments will attempt to reestablish cottonwoods, willows, and mesquite and other selected native species at specific locations to determine the feasibility of reestablishing native species along the lower Colorado River.

Using the data collected during the baseline study, the researchers have developed riparian management concepts that are concerned with wildlife enhancement, reduced evapotranspirative water loss, and the quicker passage of floodwaters. A 3-year study to test the concepts includes three revegetation test plots. There is one 50-acre plot designed to establish native vegetation on dredge spoil that also provides for passage of floodflows and wildlife enhancement. Another 25-acre plot is designed to establish vegetation on dredge spoil strictly to enhance wildlife values. This plot will be cleared of mature saltcedar and planted with vegetation better able to sustain wildlife. The third plot, a 38-acre site found on a national wildlife refuge, is being jointly funded by the Bureau of Reclamation and the U.S. Fish and Wildlife Service.

The study is designed to answer a variety of questions. For example, is it possible to reestablish natural communities? Are wildlife values in the new communities equal to predictions based on past research? How long must vegetation be watered before survival is assured? What is the cost per acre to establish native plant communities? What are the evapotranspiration rates for native and exotic vegetation? Do certain types of vegetation increase the capacity of the floodway to carry flood-flows? At the end of 3 years, if the experimental revegetation program proves viable, it will continue and an artificial manipulation of plant communities could be incorporated in management plans for the lower Colorado River.

Because of the objectivity of the Arizona State University personnel conducting the work, the studies have gained an increasing respect and credibility from the biological community. Other agencies and irrigation districts are becoming involved. In 1978, the Fish and Wildlife Service entered into a joint agreement for an experiment with the Bureau to conduct a 3-year study to reestablish native vegetation along the river.

Baseline studies of riparian vegetation along the lower Colorado River have produced another study of a different form of vegetation. We are now studying the relationship between wildlife and irrigated agriculture. This study is examining the contribution of agriculture to wildlife. It should provide concepts for managing wildlife populations in and around agricultural areas. This study has the support of the fish and wildlife agencies, the state water commissions, and the irrigation districts in the Lower Colorado River Basin.

These baseline studies and the resulting experiments in riparian management are organized and systematic management programs. Other management programs have grown out of what can only be called, from an environmental viewpoint, beneficial opportunism. We practice beneficial opportunism when we preserve and enhance conditions which occurred more or less by accident, but which are highly favorable to wildlife. For

instance, along the Rio Grande River in New Mexico, pilot channel work and training jetties have created wetland areas. Channel straightening work cut off oxbows from the main body of the river and these oxbows filled with seepage from the river or from irrigation canals. Although it was mostly saltcedar, vegetation quickly sprang up in these artificially formed wetlands. This vegetation soon attracted various forms of wildlife. This area is particularly useful to waterfowl and wading birds. One of the best known of these artificially created oxbows lies just north of Albuquerque, and the University of New Mexico uses it for nature studies.

Another example is the work being done at Topock Marsh, which is part of the Havasu National Wildlife Refuge. The marsh, a national wildlife refuge, approximately 4 miles southeast of Needles, California, is a 4,000-acre wetted and open water area located adjacent to the Colorado River on the Arizona side. It is located in one of the hottest areas of the Southwest desert.

Topock Marsh, as we know it today, came into existence during a period between 1938 and 1940 as a result of the closing of Parker Dam and the filling of Lake Havasu in 1938. Topock Marsh was not created by the simple and routine filling of the reservoir. Filling this reservoir behind Parker Dam, located 46 miles downstream, slowed the Colorado River and allowed much of its heavy load of sediment to settle out in Topock Gorge, which is located at the head of the reservoir. This in turn backed the water up even more than had originally been anticipated. In fact, the water behind Topock Gorge rose 7 feet above what had been expected and resulted in the creation of Topock Marsh. If the water level were lowered to the pre-Parker Dam elevation, only 7 acres of the marsh would be inundated, a marked contrast to the 4,000 acres of today.

The marsh's value as a wildlife refuge is directly related to water levels. This level is dependent upon the existence of Lake Havasu and related backwater sediment deposits in the vicinity of Topock Gorge. Realizing this fact, the Secretary of the Interior in 1951 directed the Commissioner of Reclamation to protect the existence of the Havasu National Wildlife Refuge, of which Topock Marsh is a unit, from water loss under the authority of the Colorado River Front Work and Levee System Act.

In 1973 the Fish and Wildlife Service requested that the Bureau of Reclamation use its 12-inch dredge "Little Colorado" to enhance wildlife habitat in Topock Marsh. Specifically, the project provided diking to improve water management and channeling to improve water circulation. An efficient sediment basin was constructed to reduce the silt load entering the marsh, and dikes were provided to separate marsh waters from Fort Mohave Indian land.

Although Topock Marsh accidentally happened as a result of filling Lake Havasu, it has produced excellent riparian vegetation and wildlife habitat, including new habitat for the endangered Yuma clapper rail. Carefully monitored dredging as conducted in Topock Marsh is one of the ways the Bureau of Reclamation is helping the Fish and Wildlife Service manage an important Southwest desert wildlife refuge.[1]

Other aspects of the Colorado Front Work and Levee System are proving beneficial to riparian vegetation. There are other backwater areas similar to Topock Marsh, but on a lesser scale up and down the river. Dr. Tash of the Cooperative Fishery Unit at the University of Arizona at Tucson has done some interesting work in the productivity of these backwaters and has published several papers. These backwater areas were designed to use daily high flows flooding the banks of the river. Other areas were formed when the river changed its course. In the past, though, these naturally occuring marsh areas were ephemeral. They would dry up beneath the desert sun. However, one of the beneficial side effects of our bank stabilization work and comprehensive marsh management scheme is that these marsh areas are lasting longer now. Today, as a result of planned bank stabilization work, these areas can be managed and their lives prolonged indefinitely.

I have summarized the principle riparian programs of the Bureau of Reclamation in its Lower Colorado Region undertaken thus far. We plan to continue our riparian vegetation studies and experiments which we

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[1] Further information about this dredging in Topock Marsh can be found in an article written by Dr. Wayne Deason and Mr. Phillip Sharpe, biologists in the Lower Colorado Region, which appeared in the November 1975, issue of the magazine <u>World Dredging and Marine Contruction</u>, and a more advanced presentation "Development of Hydraulic Structures for Improvement in Habitat of the Endangered Yuma Clapper Rail" by Deason and Sharpe made at the International Symposium on the Environmental Effects of Hydraulic Engineering Works in September 1978.

trust will lead to sound multi-use management programs for the future. Regardless of where these studies lead, the Bureau definitely plans to stay in the forefront in riparian vegetation research and management.

At this time, I would like to try and give a succinct statement about Bureau of Reclamation policy toward riparian vegetation in the Southwest. But before I do so, I would like to shift your attention away from the Southwest for a moment. Not too far from where we are meeting today, a great Southern poet, Sidney Lanier, immortalized his observations of the Chattahoochee River. He identified with this river and described the rushes and the waterweeds, the "laving laurel" and the ferns, the dewberry and the "little reeds" which lined its banks. With obvious relish he mentioned the hickory, the "poplar tall," the chestnut, the oak, and walnut, and the pine. Sidney Lanier's poem is significant not only because of the profusion of riparian vegetation which he lists, but also because he so vividly points out the deep underlying communion between the river and the plants which line its bank. Such profusion does not exist in the Southwest, but the communion is there. The river and its vegetation are one, and such a unity is as true of the Colorado River as it is for the Chattahoochee. That unity has to be one of the cornerstones of our riparian policy. Regardless of what has happened in the past, we now relize that riparian vegetation has unique and special qualities and is an integral part of the river ecosystem that needs to be protected and enhanced along with other multiple resources.

With this in mind, I would again like to shift your attention back to the West. The Bureau of Reclamation does not have a formal, specific policy about riparian vegetation. However, we believe that guide lines encompassing three major points are desirable and need to be addressed by this meeting.

1. The Bureau of Reclamation will strive to minimize impacts on the remaining riparian communities as far as it is possible. Whatever native riparian vegetation exists now will be considered a unique resource in project planning. Recommendations for replacement of riparian vegetation that is unavoidably lost as a result of project construction will be given high priority in project consideration.

2. Research on the multiple use management of riparian vegetation will be continued. As much information as possible will be gathered to facilitate the development of sound management concepts to guide us in our planning and operation of projects that affect riparian vegetation. In addition, should future water supplies become available as a result of advancing technology, research efforts will include the concept of devoting some of this water to expanding riparian habitat.

3. Where authorized, revegetation efforts will be accomplished to meet goals of multiple use management.

We realize that riparian vegetation in the West will never exist in such profusion as it does here in the Southeast. However, we hope someday that a native Western poet will be able to write a poem in praise of the thick riparian vegetation along the Colorado River just as Sidney Lanier did about the Chattahoochee here in Georgia. If so, our effort will have been a success.

Effects of Wetlands on Water Quality[1]

Harold V. Kibby[2]

Wetlands potentially have significant effects on water quality. Significant amounts of nitrogen are assimilated during the growing season and then released in the fall and early spring. Phosphorus while assimilated by wetlands is also released throughout the year. Some potential management tools for evaluating the effect of wetlands on water quality are discussed.

INTRODUCTION

During the past two days many roles and functions of riverine wetlands have been discussed. One additional role that resource managers should consider in their decisions affecting wetlands is the effect of these areas on water quality. First, what is water quality? There is no way to describe good or poor water quality; it is dependent upon the planned use of a given water body. While there are some exceptions, it is not generally possible to describe beneficial or adverse effects of wetlands on water quality. Consequently, the purpose of this paper is to describe _some_ effects of riverine wetlands on water quality without stating whether they are adverse or beneficial.

Just as all wetlands do not have all of the values prescribed to them over the last two days, it must be emphasized that all wetlands are not going to have all of the effects that are described. The effect of a given wetland on water quality is very dependent on the hydrological characteristics of the area. This is particularly true of floodplain wetlands, since floodplains are flat areas that are only periodically flooded. This flooding replenishes the water of marshes and swamps that occur in flood plain depressions. In many cases where flooding occurs only every one to four years, there is a rapid accumulation of organic matter and poor circulation of water. In these areas wetlands simply may serve as settling basins for local runoff. In other cases there is frequent exchange of water between the floodplain wetland and the adjacent river. The extent, timing, frequency and duration of the connection between the wetland and adjacent water body largely determine the effect of that wetland. This must be kept in mind when evaluating the data that are presented.

NUTRIENT DYNAMICS

There have been a number of studies on nutrient dynamics in marshes (Boyd, 1969; Boyd and Hess, 1970; Lee _et al_., 1975; Klopatek, 1975 and 1978; Boyd, 1978; Prentki _et al_., 1978; and many others) and swamp forests (Wharton, 1970; Kitchens _et al_., 1975; Bradshaw, 1977; Brinson, 1977; Odum _et al_., 1978; and others). Some authors contend that wetlands serve as a source of nutrients to adjacent water bodies while others state that wetlands are sinks for nutrients. In reality they can probably be thought of as valves taking in nutrients during the spring and early summer, and releasing them in the late summer and fall.

The nature of the soil environment in wetlands is particularly important in understanding nutrient cycling and the effect of wetlands on nutrient concentration in nearby water bodies. In upland soils, aeration and oxygen may persist to several feet, and organic material is rapidly decomposed. In wetland soils, the aerobic layer is only a centimeter or less thick. The microbes that act as decomposers quickly utilize the oxygen. Consequently, the sediment is divided into an aerobic and anaerobic zone. The differentiation of the flooded soil into these zones was first investigated by Mortimer (1941, 1942). Decomposition processes in the anaerobic zone proceed slowly, and many unoxidized decomposition products accumulate. Some of these such as methane, hydrogen sulfide, and organic acids would be toxic to aquatic organisms if they could escape. However, the oxidized layer acts as a chemical trap not only for toxic materials but for some nutrients as well.

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[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Calloway Gardens, Georgia, Dec. 11-13, 1978.

[2]Research Biologist, U.S. Environmental Protection Agency, Corvallis, Oregon.

Nitrogen

Of particular interest is the role of wetland soils on nitrogen balances. In aerated soils ammonia is readily oxidized to nitrate, whereas under anaerobic conditions, ammonium tends to accumulate and be denitrified. Not only is nitrate not produced but when it is added to a flooded soil, it is also subject to denitrification. Many wetland areas, at least coastal wetlands, are nitrogen limited; such denitrification further reduces nitrogen supplies that could be used for primary production. While denitrification is the principal way nitrogen is lost from marsh soils, a major source of accumulation of nitrogen in the soil is from organic matter. The total nitrogen content of the soil tends to remain fairly constant throughout the year (Buckman and Brady, 1969).

Field studies on the role of wetlands in nutrient dynamics generally have been either 1) input/output studies, or 2) uptake of nutrients by plant species. In the past each of these methods has had its limitations. Based on input/output studies, it would appear that nitrogen is assimilated by the plants during the growing season, and then mostly organic forms of nitrogen are released during the fall or early spring (Brinson, 1977; Simpson *et al.*, 1978; Klopatek, 1978; and many others). Significant amounts of nitrate are removed from the water as it flows through the wetland (Lee *et al.*, 1975; Patrick and Reddy, 1976; Richardson *et al.*, 1978). Horicon Marsh, Wisconsin, has typical input values which are 10 mg/l of ammonia and 1-2 mg/l of nitrate, whereas the concentration in the outflow is typically less than 0.2 mg/l for both ammonia and nitrate (Lee *et al.*, 1975). There is significant uptake of nitrogen by the marsh community during the spring months. Lee (1975) reported that in marsh water during the spring and fall months high values of inorganic nitrogen result from nitrogen not being assimilated by the plants and do not necessarily represent release from the plant community.

One short-term input/output study of nutrient levels on the Santee River Swamp (Kitchens *et al.*, 1975) did not include sufficient hydrological data to estimate rates of concentration change. However, the authors conclude that concentrations of nitrogen regardless of the form were less in outflowing water than inflowing. Wharton (1970) also reports that swamp forests act as nutrient sinks. Further, mixed hardwood swamps have been shown to remove up to 99 percent of the nitrogen in sewage effluent (Boyt, 1976). Cypress domes are also efficient filters for nitrogen (Dierberg and Brezonik, 1978).

One of the major problems associated with input/output studies in the past is that they lack sufficient hydrological data to calculate precise nutrient budgets. Precise data on both the history of the water masses and ground water exchange are needed to accurately calculate these fluxes. Much of the "washout" from these wetland areas may occur during storm events. The export from wetlands under these conditions has not been studied in any detail.

A second way of looking at the effects of wetland communities on water quality is to examine seasonal changes in the concentration of the nutrient within the plant community. There are a number of inherent problems associated with this method as well, such as the fact there is no way to account for immobilization within the sediments or denitrification. Consequently, these techniques will give a minimal estimate. Most of these studies have not been designed to examine the effect of the wetland on nutrient concentrations. However, careful examination of the data will allow us to elucidate general patterns of annual cycling of nitrogen. While a number of workers have examined nutrient concentrations in wetland species, the summary of seasonal concentration data presented here is from a *Carex lyngbyei* community in Oregon (Table 1). The higher concentrations of nitrogen in the dead plant material may be due to one or a combination of several factors. First, the dead tissue is more porous than living tissue, and there may be contamination from sediments. Second, decomposition may be selectively removing other components. Third, the nitrogen analyses did not distinguish between microbial nitrogen and plant nitrogen. Hence, more microbes may be associated with the dead plant material.

Table 1.--Concentration of nitrogen in *Carex lyngbyei* (%).

	Live	Dead
Winter	1.63±.03	1.67±.07
Summer	1.37±.03	1.43±.07
Fall	1.40±.06	1.98±.08

When concentration data are coupled with primary production, live biomass, dead biomass and mortality, fluxes from various compartments can be calculated. Live and dead biomass were determined in the field using seven randomly placed quadrats at six-week intervals from March to October and eight-week intervals during the winter. Net primary production and mortality were both calculated using the method described by Lomnike *et al.* (1968).

Uptake includes material that is taken up by

the roots and transferred to the shoots and material that is stored in the roots and subsequently transferred to the shoots. Two values for uptake of nitrogen were calculated, one using the change in nitrogen in the living component from t_1 to t_2 plus that lost to mortality during the time period. The second

$$(1) \quad U = (L_{T2} - L_{T1}) + M_{t1t2}$$

method of estimating uptake was calculated by multiplying the net primary production for the time period by the concentration of nitrogen in the live material. Uptake of nitrogen using the net primary production method was 25 gms/m^2/yr. The annual uptake using method one, i.e. balancing the nitrogen in the standing crop from t_1 to t_2, resulted in an estimate of annual uptake of 20 gms/m^2/yr. The difference between the numbers could be explained in two ways--1) experimental error, or 2) leaching of nitrogen by live plants. If we assume the difference is leaching, then on an annual basis it can be said that there is a leaching of 4.97 gms/m^2/yr or 25 percent of the uptake. Klopatek (1978) reported a leachate loss from a Scirpus fluviatilis of 7.34 gms/m^2/yr or 42 percent of total uptake. Regardless of the method used, as might be expected, the most active period of uptake was from March through June.

Mortality flux was calculated by multiplying concentration in the dead community by the rate of mortality. Output was calculated by adding the biomass from mortality (MB_{t1t2}) during the time period to the dead biomass at the beginning of the time period (DB_{t1}), and subtracting the dead biomass at the end of the time period, then multiplying by the concentration of nitrogen in the dead material at the beginning of the time period (CD_{t1}).

$$(2) \quad MF = [(MB_{t1t2} + DB_{t1}) - DB_{t2}]\, CD_{t1}$$

The mortality flux which includes fragmentation, leaching and excretion allows for material to recycle to adjacent systems. However, this flux does not tell us the quantity of material necessarily re-entering an adjacent water body. This is because some of the loss is fragmentation of plant material that will be subsequently buried. Further, some nitrogen will be lost to water by excretion and leaching. These latter have not been measured. The largest loss of nitrogen from the community occurred during the spring and then again in the fall and winter (Figure 1). The loss in the spring and early summer was from the mat of dead Carex that had grown the previous year, died in the previous fall and winter, and had not previously broken off and washed away. The important thing to remember is that the majority of the nitrogen exported from the community during this time period is not in a form which

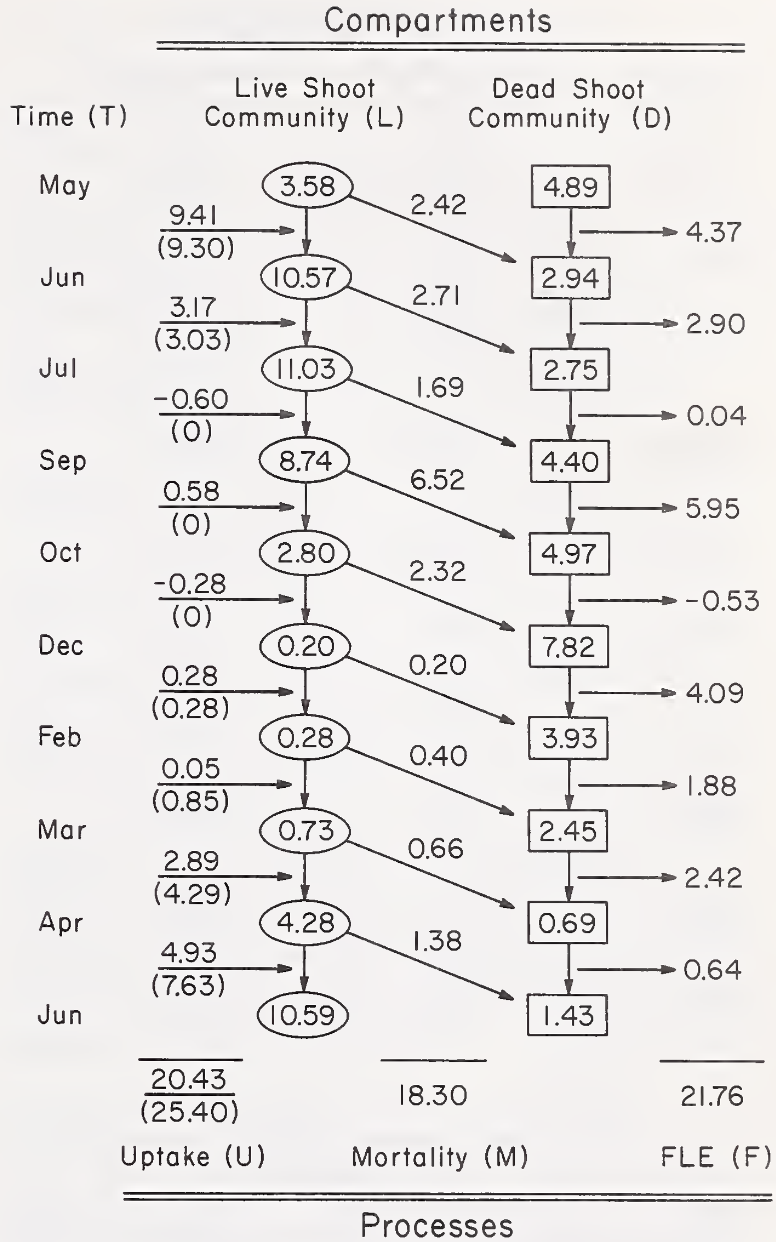

Fig. 1.-- Uptake and release of nitrogen in a Carex lyngbyei community (gm/m^2).

is immediately available for phytoplankton production downstream.

Phosphorus

A second nutrient of major importance to freshwater aquatic systems is phosphorus. Wetlands, whether they are swamp forests or marshes, tend to be very leaky in relation to phosphorus (Prentki et al., 1978; Klopatek, et al., 1978; Valiela and Teal, 1978; and others). At Horicon Marsh in Wisconsin, in spite of the fact that a large percentage of the reactive phosphorus was removed, the concentration of phosphorus in the outflow was sufficient to stimulate phytoplankton in downstream areas (Lee et al., 1977).

Using the techniques described in the nitrogen section, annual phosphorus flux has been calculated for the same Carex community in

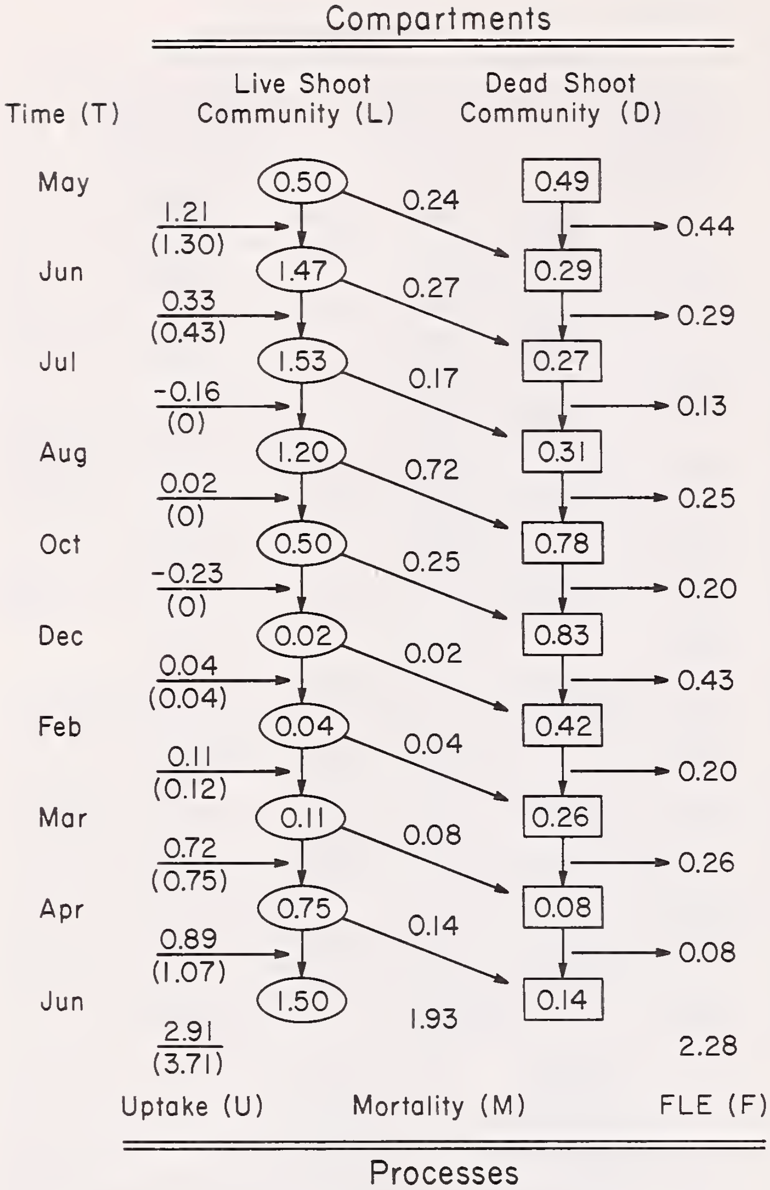

Fig. 2.-- Uptake and release of phosphorus from a Carex lyngbyei community (gm/m^2).

Oregon (Table 2, Figure 2). Unlike nitrogen

Table 2.--Concentration of phosphorus in Carex lyngbyei (%).

	Live	Dead
Winter	2.40$\pm$.06	1.78$\pm$.04
Summer	1.93$\pm$.07	1.43$\pm$.09
Fall	2.40$\pm$.10	2.20$\pm$.10

there appears to be a significant release (fragmentation and leaching) from the dead plant community throughout the year. If the difference in uptake values between those calculated using net primary production (3.71 $gms/m^2/yr$) and those necessary to balance the concentrations in the biomass at t_1 and t_2 (2.91 $gms/m^2/yr$) is assumed to be leaching from the live community, then we can say that on an annual basis 0.80 $gms/m^2/yr$ of phosphorus leached from the live Carex community. This represents 22 percent of the uptake and may be compared to a release of 58 percent of the uptake reported for Scirpus fluviatilis reported by Klopatek (1978).

This discussion on phosphorus and nitrogen was not intended to be a complete literature review, and indeed has only touched on many of the nutrient flux studies in wetland areas. A review of these studies indicates two things of importance. One is that to fully understand the effect of wetlands on nutrient concentration in adjacent waters, greater emphasis and a better understanding of hydrology need to be pursued. Second, a better understanding of the effect of catastrophic events such as major storms needs to be developed.

METALS

Metal uptake by riverine and floodplain wetlands may at times be significant. While a number of authors have discussed uptake of metals by wetland plants, let me use an example from our work in Oregon (Gallagher and Kibby, 1978) which was concentrating on the determination of natural cycles of selected trace metals into the living plants, from the living plants to the dead plants, and from the attached "dead plant community" to the rest of the ecosystem. Table 3 shows a set of "typical data" for Carex lyngbyei. While metals may be removed from the

Table 3.--Uptake and fragmentation of heavy metals in a Carex lyngbyei community (values - per m^2/yr).

Metal	Unit	Uptake	Fragmentation
Cr	mg	38	39
Cu	mg	20	18
Fe	gm	14	15
Mn	mg	655	676
Sr	mg	76	75
Zn	mg	73	74

water/sediment system by the plants, it must be kept in mind that much of this material is readily available for transfer up the food chain. This can become particularly critical for managers that deal with contaminated sediments or the disposal of dredged material.

SEDIMENTATION

The ability of a stream to carry sediment is largely dependent upon the velocity of the stream—the greater the velocity, the greater the load that can be transported. Suspended solids include both organic and inorganic materials; however, most of these materials are inorganic particles of clay, silt, sand, etc. While these small particles are chemically inert themselves, they do have an enormous surface area and dissolved chemicals in the water may be adsorbed to them, and removed from the water column by sedimentation. Floodplains and wetlands are areas where water velocities are greatly reduced compared to the main channel, hence much of the sediment load is deposited in wetland areas. Consequently, wetlands serve a dual role of removing both sediment and chemicals from the water. One example of the effect of riverine wetlands on sedimentation can be seen in the Atchafalaya Basin of Louisiana. Of the 72 million cubic yards of sediment entering the basin at Simmesport, about 23 million cubic yards are deposited in the basin annually (Gagliano and vanBeek, 1975).

ORGANICS

Wetlands, including both swamps and marshes, often have a profuse growth of aquatic life. Consequently, many marshes discharge high quantities of organic matter. This discharge of organic matter may effect water quality either by increasing the color or adding to chemical oxygen demand values. Color could be an important water quality characteristic since it is often difficult to remove by water treatment processes. High organic matter also can influence water quality by increasing the chlorine demand of water or by competing with other organics for adsorption sites on activated carbon in water treatment processes.

In summary of this section there are no easy answers to the effect of wetlands on water quality. Resource managers must first determine the use they desire for the water, look for the potential problems of achieving and maintaining that use, and then develop a management plan. In developing that management plan, thinking must be innovative and original, and traditional values as well as all possible consequences should be explored. For example, I have never seen any research on the effect of a floodplain swamp on saltwater intrusion. Yet, as Gallagher (1978) points out, the Snuff Box Swamp along the Altamaha River in Georgia may be just such a place. During the spring flood, the swamp fills. Then during the summer months it gradually drains, in effect providing flow augmentation to the main river.

SCIENCE AND MANAGEMENT

While we should be moving toward resource management on a watershed and regional basis, and we are moving in that direction, decisions will continue to be made on individual projects. The scientific community must recognize this fact and also recognize that every decision cannot be backed up by good science. Morgan (1978) states that good decision making, or policy analysis and good science do not serve the same ends. "Good policy analysis recognizes that physical truth may be poorly or incompletely known. Its objective is to evaluate, order and structure incomplete knowledge so as to allow decisions to be made with as complete an understanding as possible of the current state of knowledge." Scientists must pursue physical truths and advance the state of the art, while recognizing decisions are going to be made before all data that are necessary for absolute truth can be collected. In recognizing this, scientists have the responsibility to give managers tools by which they can evaluate, order and structure incomplete knowledge. It should be recognized that by its very nature data that are collected, often in a hurry, are not of the quality by which scientific theories may be advanced. Resource managers on the other hand have the responsibility to collect as sound and complete data as resources including time permit. They also have the responsibility of utilizing the data that are collected with due caution and recognizing their limitations.

We must recognize that wetlands are a natural resource that should be used by man, and that even if we could, not every area should be preserved forever. Thus, we are left with a most difficult task of making tradeoffs between wetland areas. There is no standard methodology for the assessment of the ecological value of a wetland, nor would I propose, in spite of the work of some very eminent ecologists, that there is an effective way of putting a dollar value on wetland systems. In spite of these difficulties, resource managers must continue to make decisions.

It is in this spirit that I offer the following suggestions. These techniques will not offer absolute truths. In fact, there will be large errors associated with them. They are intended, however, to give managers a feeling for the role of a specific wetland on water quality.

First, we must determine if the project is of sufficient size and magnitude to require a full-blown Environmental Impact Statement or if it is relatively small and must be evaluated with a minimum of data. If indeed it is a large project requiring an Environmental Impact Statement, then I feel the time and effort should be

Table 4. Annual Net Primary Production for Selected Freshwater Wetland Species.

State	Species	EOSL (g/m^2) Range	EOSL (g/m^2) $\bar{x}$	EOST (g/m2) Range	EOST (g/m2) $\bar{x}$	NPP ($g/m^2/yr$)	Reference
Alaska							
	Carex aquatilis				25.5		Teiszen, 1972
Delaware							
	Phragmites communis		1380		6075	3550	Linthurst, 1977
	Zizania aquatic		866				Whigham & Simpson, 1975
	Bidens sp.		1026				" " "
	Phalaris arundinacea		566				" " "
	Lythrum salacaria		2104			2100	" " "
Iowa							
	Typha glauca	758-2106	1314			2297	Vander Valk & Davis, 1977
	Phragmites communis	777-1110	943				" " " "
	Scirpus acutus	751-951	851				" " " "
	Carex spp.	523-2231	927			2858	" " " "
	Sparganium eurycarpum	474-1054	721			1066	" " " "
	Scirpus fluviatilis	450-791	547			943	" " " "
	Sagittaria latifolia		460				" " " "
	Scirpus validus	243-602	398			713	" " " "
	Bidens cernua		598				" " " "
Louisiana							
	Eichornia crassipes				1478		Penfound & Earle, 1948
	" "				1276		Penfound, 1956
	Phragmites communis		990				Gosselink, *et al.*, 1977
Maryland							
	Phragmites communis		1367		1714		Flemer, *et al.*, 1978
	" "		1451			1678	Johnson, 1970
	Zizania aquatica		1178		1313		Flemer, *et al.*, 1978
Michigan							
	Glyceria striata	30-45	37				Parker & Schneider, 1975
Minnesota							
	Carex rostrata		852			738	Bernard, 1974
Mississippi							
	Phragmites communis					2330	de la Cruz, 1974

Nebraska				
Typha spp.		416		McNaughton, 1966
New Jersey				
Zizania aquatica	1600			Good & Good, 1975
Phragmites communis	1074			Walker & Good
Acorcus calamus	605			McCormick & Ashbough, 1972
Acnida cannabina	768			Good, et al., 1975
Sagittaria latifolia + T. augustifolia (mix)		1380		Jervis, 1964
Special Freshwater Marsh Types (NJ)				
Cattail Marsh		1700		Jervis, 1969
Sedge-shrub Marsh		1350		" "
Sedge-swale Marsh		1330		" "
Open-aquatic Marsh		1200		" "
New York				
Phragmites communi		2686		Harper, 1918
Typha augustifolia		1728		" "
Typha latifolia		1357		" "
Carex lacustris			965	Bernard & Solsky, 1977
			857	Bernard & MacDonald, 1974
Carex rostrata			540	Bernard & Hankinson, 1978
Oklahoma				
Typha latifolia	1527			Penfound, 1956
Typha sp.		730		McNaughton, 1966
Pennsylvania				
Bidens sp.	900			McCormick, 1970
Lythrum salacaria	1373			" "
South Carolina				
Typha latifolia	680			Boyd, 1970
Scirpus americanus	145			" "
Texas				
Typha sp.		1336		McNaughton, 1966
Virginia				
Zizania aquatica		560		Wass & Wright, 1969
Leersia oryzoides		1545		" " "
Nuphar advena		245		" " "
Typha augustifolia		930		" " "

made to collect at least growing season data and preferably yearly data on the parameters previously discussed. If the project is a relatively small permit application, as most of them are, then full-blown, large scale field exercises are too expensive and time consuming. It is under these conditions that some of these techniques may be used to evaluate marshes.

Next, the most important aspect of evaluating the effect of a given wetland on water quality is determining the hydrological characteristics of the area. Is it connected to the water body so that there is a continuous or near continuous exchange of water, nutrients, etc. or is there only periodic exchange, say every three or four years. There is no rule of thumb on how much exchange is important for water quality effects. However, if the area is fairly extensive and/or exchanges water at least annually, it would be wise to carefully consider potential effects on water quality.

If possible, estimate net primary production of the area. This may be done in one of several ways. If there is literature available from your region for the dominant species, then an estimate of productivity may be gained from that source. Table 4 gives a partial list of that literature. If no literature is available, then if you are fortunate and are evaluating a permit in the late summer or early fall, you may be able to go to the field and gain a quick estimate of maximum standing crop biomass at the end of the growing season. If you are able to go to the field, one should harvest a minimum of seven $0.1m^2$ plots in each plant community present at the project site. These samples must then be returned to a laboratory, weighed, dried in an oven at 60^o C, and reweighed. The end of season total maximum standing crop biomass can then be estimated. For most species this represents a minimum estimate of net primary production. Finally, as a last resort, you might use Table 5.

Table 5.--Estimates of net primary production for freshwater marsh plants.

Plant Size (meters)	Density of Stems	NPP ($gms/m^2/yr$)
0.5	Low/Medium (40%)	500
1	Medium (50%)	1000
1.5	Medium/High (70%)	1500
2	High (90%)	2000

These are very arbitrary data but are intended to give resource managers, who have no feeling for primary productivity of an area, general guidance. What good is knowing the net primary production (NPP) of a wetland? One thing we can do is couple NPP with concentration of nutrients in the plants to calculate nutrient removal capacity of the marsh. Both Hutchinson (1975) and Boyd (1978) list values for chemical composition of wetland plants. Boyd cautions, "No average 'chemical' composition for an individual species or ecological grouping of species based on data from the literature would be reliable. Therefore, actual measurements should be made in studies requiring data on chemical composition." Since people evaluating many permits do not have the luxury of the time or resources to carry out desired analyses, we will proceed. Boyd (1978) reports a range of values for nitrogen from about 0.93% to a maximum of 3.95%. Hutchinson (1975) reports a range of 0.71% to a maximum of 5.29%. Both authors have mean values of around 2.3% (Table 6). Using a value for Net

Table 6.--Concentrations of nitrogen and phosphorus in wetland plants.

	Range of Reported Values	Mean of Means[1]
Nitrogen		
Nitrogen	0.71-5.29%	2.30±.52
Phosphorus		
Phosphorus	0.08-1.00%	0.26±.10

[1]Mean of Means--the mean of mean values reported by Hutchinson (1975) and Boyd (1978).

Primary Production of 1300 $gms/m^2/yr$ for Typha in New Jersey and a value for nitrogen of 2.3%, we could say that the plants in a ten-acre marsh would remove 300 grams of nitrogen per year. To provide a range of values we might also assume a one percent nitrogen concentration. This would then let the decision-maker know that this marsh has a potential for removing from 130 to 300 gms/nitrogen/year.

There are obviously two sources of error associated with this type of analysis: (1) estimating primary production, and (2) estimating nutrient concentration in the plant material. Certainly the error is large enough that no scientific theory should be advanced using calculations such as those indicated previously. However, resource managers even if they never write down the basis of their decision on a small permit application could use such calculations to gain a better understanding for the potential effects of a given wetland on nutrient dynamics.

While decisions will continue to be made on the best available data, there are no standard acceptable methodologies for assessing the ecological value of a wetland. Applying broad generalizations about the value of wetlands to

cite specific cases will in the future tend to hurt the cause of wetland protection because so many times data can be presented which will "prove" that the generalization does not exist for a particular wetland. In large projects, scientists can gather pertinent data and interpret the data for the manager who has the more difficult part of the job, that being to make a good decision. On small permits the manager has both jobs, that of gathering relevant information and making the decision. Communication between scientists and resource managers is a must. Conferences such as this one go a long way in developing these communication lines.

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Multipurpose Development Programs in Riparian Ecosystems: The TVA Experience[1]

Charles J. Chance[2]

INTRODUCTION

Under the TVA Act of 1933, the Tennessee Valley Authority has the unique responsibility for promoting the physical, social, and economic development of the TVA region, including the responsibility for providing flood control on the Tennessee River and its tributaries, improving navigation, and generating electricity. TVA is a corporate Agency of the Federal government and operates somewhat as a private corporation. As such, it demonstrates great flexibility in carrying out its mission.

Focusing on the theme of this symposium, TVA is charged specifically with the broad task of planning and implementing human and natural resource development programs on its own lands and in cooperation with landowners, corporate entities, government bodies (local, regional, and state), and other Federal agencies. These actions can take place in any of the 125 counties within the seven States of Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia which comprise the Tennessee Valley watershed region.

Within this region, the Tennessee River drains a watershed of 40,910 square miles (10.6 million hectares). The Tennessee River is the fifth largest in the United States and the seventh largest in North America in terms of discharge. Its system of dams and reservoirs on the mainstream and its tributaries makes the Tennessee River the best controlled major stream in the entire world--and a river system with one of the most diverse riparian ecosystems in terms of human and natural resource development.

From the human resource development standpoint TVA has emphasized assistance to communities and landowners to reduce or avoid flood damage by identifying the limits of floodwaters and furnishing minimum safe flow elevations to guide construction efforts. This, coupled with more recent innovative actions, will be defined further in this paper.

From the natural resource side, TVA began by setting aside significant riparian and aquatic wetlands in its ownership for wildlife management purposes by State wildlife agencies and the Fish and Wildlife Service. More recently, TVA has instituted land use planning systems on Federal and private lands to achieve balance between protection of natural values and prudent development to meet recreational, agricultural, industrial, wildlife, and flood storage commitments while maintaining scenic protection goals. This action has been addressed more completely in another paper at the symposium by Ginn and Burbank[3], but some elaboration shall be given here.

NATURAL RESOURCE PROTECTION AND DEVELOPMENT

The recent Executive Orders on the "Protection of Wetlands (EO 11990)" and "Floodplain Management (EO 11988)" formally require that TVA's decision-making clearly recognize that floodplains and wetlands have significant environmental values requiring Federal protection, and that activities in flood plains (which include riparian ecosystems as defined by this symposium) should be limited for public health, safety, and welfare reasons. Accordingly, in line with the recommendations contained in these Executive Orders and the United States Water Resources Council (WRC) guidelines (43 Fed. Reg. 6030 (1978)), these new directives have been incorporated into TVA's multidisciplinary process for implementing the National Environmental Policy Acts of 1969 (NEPA). The procedures, coupled

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[1] Paper presented at the National Symposium on Strategies for the Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

[2] Chief of Special Services, Division of Forestry, Fisheries, and Wildlife Development, Tennessee Valley Authority, Norris, Tennessee.

[3] Ginn, Richard H. and James H. Burbank. 1978. Protecting riparian ecosystems from competing urban pressures--the Swan Creek experience. Presented at the National Riparian Ecosystems Symposium, Calloway Gardens, Georgia, December. 17 pp.

with the NEPA process, will ensure that the goals of flood plain management and the protection of wetlands are achieved.

Consideration will be given in the decision-making process to the public benefit, both aesthetic and physical, to be derived from the preservation of wetlands and flood plains. Flood plains development and wetland alteration are not prohibited in all cases, but rather TVA's policy is to be consistently against such activities unless no practical alternatives exist. TVA acts to reduce flooding risk, minimize adverse impacts, and preserve flood plain and wetlands values. Planning programs are included as activities which require evaluation for flood plain and wetland impacts even though they do not result in a physical change to the environment.

TVA provides leadership and takes action to avoid the long- and short-term impacts associated with the occupancy and modification of flood plains or the destruction and modification of wetlands, and to avoid the direct or indirect support of flood plain development or new construction in wetlands unless no other practicable alternative exists. TVA shall also recognize the need to ensure future preservation and restoration of flood plains and wetlands.

Although the concept "wetlands" is broader than the theme of this symposium, it is important that you know TVA's interpretation of this ecosystem, within which the drier riparian zone exists. We view wetlands as those areas inundated by surface or ground water with a frequency sufficient to maintain, maintain, a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction. Commonly accepted wetland species will comprise a substantial portion of the biological community. Opportunistic upland plants adapted for colonization of disturbed areas exposed by controlled receding water levels but incapable of surviving sustained reflooding during the growing season will not be considered as wetland species. Wetlands generally include swamps, marshes, bogs, sloughs, potholes, wet meadows, river overflows, mud flats, and natural ponds or similar areas where soil and water characteristics and biological communities reflect the influence of predominantly wet conditions on inspection, even if the inspection would occur in a normally dry period of the year. Areas that once supported a wetland community but have been essentially converted to dry land for agricultural or other purposes will not be considered to be wetlands for purposes of Executive Order 11990 compliance.

The problem of loss of wetlands arises mainly from unwise land-use practices. In recognition of this situation, TVA has been instrumental in setting aside key wetland areas on those Federal lands it controls. Over the years TVA has provided more than 190,000 acres (76,900 hectares) of land and water to Federal and State agencies for waterfowl and upland wildlife management areas and refuges, nearly one-third of its reservoir holdings. Last season these areas attracted over 93,000 Canada geese and 330,000 ducks and supported a waterfowl hunting recreation valued at 1.1 million dollars.

Wildlife does not exist in a vacuum, however. It must share space with other land uses such as residential, agricultural, industrial, and general recreation developments. Conflicts have been the rule, rather than the exception in the past. Today this is being changed by the deliberate efforts of TVA to involve all interested parties in land use planning, striving to achieve the best fit among all these interests. One of the most successful efforts to date has involved the Decatur-Athens region in north Alabama. Using the multidisciplinary, multiagency approach, all interests were blended so that one of the most important riparian waterfowl areas in Alabama was assured of its continued and enhanced existence. The Swan Creek Wildlife Management Area on Wheeler Reservoir became the first such unit on a TVA reservoir to be granted a 30-year recreation easement. This has guaranteed the stability and tenure necessary for the State to realize its long-term capital improvement plans. And this action shall help meet TVA's long-range goal for optimum migratory waterfowl development on its properties.

Swan Creek is indicative of the Agency's interest and commitment to protect, and, where possible, enhance critical wetland-riparian properties. Rather than being the exception it heralds a new era of public participation in TVA's planning and decision-making process. It assures that, where appropriate, wetland and flood plain values will be a part of the total mix of objectives and concerns which guide future programs initiated or sponsored by TVA.

Flood Damage Reduction Methods of TVA

The paradoxical purpose and plight caused by man's use of riparian flood plains have been described by Wall[1] as follows:

> There are many sound and logical reasons to explain why people locate activities on the flood plains. Historically it was essential that we locate there. Because we needed to be there, we developed a Federal program of protective works. Because of the success of our protective works, and other factors, we have accelerated our development of flat easily developed flood plains for these historic purposes and for many other uses. It is ironic that this increased development in flood plains is causing the nation a serious problem. The problem confronting the Nation today is deciding how we can best utilize the resources provided by our flood plain lands while minimizing adverse consequences of our acts. Although flood plain lands are desirable and attractive for high density urban and industrial development, they also present great hazards to human lives, to our investments, and even to the future direction of entire communities.

TVA's approach to minimizing flood problems in the Valley is basically twofold: Regulating the Tennessee River and its major tributaries with the system of dams and reservoirs--this affords substantial protection for areas adjacent to the main waterways; and for those communities located beyond the influence of the reservoir system, conducting a vigorous program of assistance to communities in the development of effective flood plain management programs.

River Management

Seasonal operating plan--TVA manages its water control system in harmony with the normal annual rainfall and the resultant run-off. The flood season usually begins in December and the multipurpose reservoirs are drawn to low levels by that time to provide storage space for the major storms that can be expected. As rainfall occurs during the winter, the reservoirs are allowed to rise gradually until April and more rapidly thereafter. Starting in late spring or early summer, the water is drawn out gradually to supplement the natural flow of the stream for navigation, power production, and water supply. Drawdown becomes more rapid during the drier fall months. This lowers the reservoirs, readying them for the rains in the next flood season. By late December, the reservoirs are at their low levels once more, completing the annual cycle.

Flood Plain Management

The traditional approach to local flood damage reduction has been to build dams, channels, or levees, but experience has proven that although the structural measures reduce the damage potential, they are often not sufficient when used alone. In some cases, flood losses after construction have actually increased because of continued and often increased flood plain encroachment. TVA's highly acclaimed program of flood damage abatement is based on the fact that communities themselves can do much to minimize flood losses by prudent flood plain utilization.

Comprehensive flood damage prevention--In a March 1975 report to Congress, the Comptroller General of the United States said that TVA's high degree of success "in getting localities to take action to reduce flood losses can be partially attributed to its comprehensive approach to providing flood relief." This diversification of effort includes helping communities assess the extent of their problem by providing flood reports recounting the magnitude of historical floods and potential future floods. Maps are included which show the stream channel and the area adjoining the stream which will be flooded during periods of high streamflow. If requested, additional assistance is provided in data interpretation, and advice is given in enacting effective flood plain ordinances.

With this information about potential flood areas, TVA works with community and State planners to develop effective flood plain regulations. These regulations allow developers to make some use of the flood plain, but also provide an open floodway to handle flood flows without causing serious damage. Such regulations are essential in any effective plan to reduce flood damages. Over 100 Valley communities have now officially adopted flood plain regulations, usually as a part of their zoning ordinances, subdivision regulations, or both.

In addition to its flood reports, TVA provides engineering and other technical advice and consultation to State and local officials in assisting them in planning for

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[1] Wall, Glenn R. 1974. Two decades of flood plain management--the TVA regional experience. Presented at the Land Use Issues Conference, Richmond, Virginia, May 13-14. 14 pp.

flood damage prevention or abatement. Public decision-making processes are established to develop plans for considering a variety of elements which will help reduce damages. In many cases, the flood damage prevention activities evolve into a comprehensive redevelopment program. In communities where this approach has proven successful, a flood study committee has been appointed to consider a variety of elements and to determine the combination that will provide the best solutions to the local problems. These may include flood control works, flood proofing of buildings, flood forecasting, zoning, subdivision regulations, building codes, developmental policies, city policies in controlling extensions of utilities, use of open spaces in parks, redevelopment of flood-prone areas under renewal programs, relocation programs, warning systems, and other elements. TVA, working with and through the proper State agency, provides engineering and other technical assistance and guidance to the local community.

When the community's plan is completed, TVA is frequently requested to provide assistance in putting it into effect. Such assistance may involve both technical and financial help.

TVA also cooperates with the Corps of Engineers, the Soil Conservation Service, and other Federal agencies in exchanging information and coordinating activities to solve local flood problems. TVA assists communities in establishing eligibility for flood insurance under the National Flood Insurance Program. To date, TVA has conducted flood insurance studies of various types for more than 300 communities. The number of communities in the Valley now eligible for flood insurance has increased from 158 in 1975 to 215 in 1977. Also, in cooperation with the National Weather Service, TVA assists in the establishment of flash flood alarm gages or locally operated self-help flood forecasting procedures.

BENEFITS FROM FLOOD REDUCTION

Reservoir operation--Since its inception, operation of the TVA multipurpose dam and reservoir system has prevented flood damages that would have amounted to more than $1.9 billion. At Chattanooga, perennially one of the hardest hit areas, average annual flood losses have been reduced to less than 2 percent of those that would have been suffered from the unregulated river system; accumulated damages averted at Chattanooga total nearly $1.7 billion.

Elsewhere in the Valley, prevented damages have risen to approximately $168 million, and outside the Valley, on the lower Ohio and Mississippi Rivers, nearly $80 million. In addition, the ability of the reservoir system to reduce flood heights along the Mississippi River levees that guard six million acres of productive land is estimated to increase the value of that land by $150 million, bringing total benefits to more than $2.0 billion, nearly 10 times the $208.8 million capital investment allocated for flood control and over 15 times the $128.9 million accumulated flood operation expense.

Local flood projects--Local flood control projects built by TVA also contribute significant benefits. These include two small dams upstream from Bristol, Tennessee-Virginia, and improved channels at Coeburn, Virginia, and Red Bank, Sevierville, Oliver Springs, Dayton, and Briceville, Tennessee. Accumulated flood control benefits from these projects now total approximately $9 million, which equal the total cost of the project.

Wall summarized TVA's human resource development experience in the following manner:

> The TVA program has evolved in response to recognized needs. Initially, its purpose was to provide information so individuals, businesses, and communities could avoid areas subject to flooding. Experience demonstrated information alone was insufficient. Consequently, emphasis was then placed on flood plain regulations. In many cases this approach alone could not work. The program was then expanded to guide local leaders in utilizing both corrective (structural) and preventive (nonstructural) measures. After additional experience the program was again expanded to find ways to meet additional needs. The experience gained in this newest activity demonstrates how the interdisciplinary approach can be used to solve flood problems while also solving other community problems.
>
> The Local Flood Relations Program has demonstrated that flood damages can be markedly reduced by cooperative action. This is not done by either eliminating all uses of the flood plain or by eliminating floods. Rather it must be done by using a variety of elements that must be closely coordinated. An effective Federal-State-local cooperative program permits each level of action to complement the others. The TVA

regional experience has also demonstrated clearly that most communities will need continuing assistance after flood information is made available to them. Technical personnel who furnish this assistance must be able to overcome disappointments and frustrations which often occur when trying to gain public support for local action. These [misguided] efforts often fail, however, as more and more communities adopt comprehensive flood loss reduction programs for there will be greater rewards in cooperating to reduce damages. We are convinced this cooperation is essential if our citizens are to be free from the devastation that will come from unwise land use.

The point being made is that flood plains should be used--but for a purpose compatible with local, regional, and national objectives. If there is a stream or waterway in a community, the threat of flooding should be recognized. Disregard the hazard and all will continue to add to the swelling subsidies to improper flood plain occupancy, and to the heartaches and tragedies that are sure to follow. By taking proper actions to see that flood plains are used wisely, individuals, the community, the State, and the entire nation will benefit.

In conclusion, the TVA experience has been an evolutionary, and at times, revolutionary blending of construction, protection, planning, and public involvement in developing the natural and human resources primarily associated with the riparian ecosystem of the Tennessee River Valley.

Opportunities for Maintenance and Rehabilitation of Riparian Habitats: Eastern United States[1]

John Cairns, Jr.,[2] Jay R. Stauffer, Jr.,[3] and Charles H. Hocutt[3]

Abstract.--Although many ecosystems have been damaged, the recovery process has not been studied carefully. However, there is compelling evidence of at least partial recovery for both terrestrial and aquatic systems. It is also clear that some ecosystems recover more slowly than others and that some types of perturbations have longer lasting effects than others. We need (1) means of predicting rates of recovery, (2) management techniques to enhance the recovery process, and (3) methods for maintenance of restored systems and perturbation prevention for those that have not been damaged. This paper addresses these topics.

INTRODUCTION

This paper is divided into two sections since the assigned title covers both maintenance and rehabilitation of water quality. These two goals require quite different strategies although some of the methods used may be equally valuable in achieving both.

OPPORTUNITIES FOR MAINTENANCE

Webster's Third New International Dictionary Unabridged (1968) gives on page 1362 a definition for maintenance as the "act of maintaining, protection..." or "the labor of keeping something...in a state of repair or efficiency" or alternatively "the action of preserving or supporting (as a condition or institution)." The strategy for maintenance of quality or condition is the same whether in an industrial process or for water quality--both require a quality control system. The essential components of a quality control system, whether it be ecological or industrial, are: (a) sensors at critical points throughout the system, (b) regular, preferably rapid, generation of information and relay to a data collection and analysis center, and (c) a headquarters organization capable of taking immediate corrective action when the system is in disequilibrium or outside desirable boundries. There is really little difference in the strategy or organization between either an industrial or an ecological quality control system except in the type of sensors used and the parameters assessed. The operational prerequisites and strategies are identical. It seems curious, therefore, that a highly industrialized society, such as the United States of America, known for its effective industrial quality control system with an economy based on its efficacy, has been so reluctant to adopt a similar quality control system strategy for maintaining and

[1]Paper presented at the National Symposium on Strategies for the Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

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protecting ecological quality. This is not due to a deficiency of methods since as Westman (1972, 1974) notes, we have made little use of methodologies available for the last 30 years and would have been markedly better off if they were in use. Without question, present methods could be improved greatly, although the likelihood of a massive effort toward improvement is remote unless there is a stronger indication of immediate use.

The maintenance of ecosystem quality requires three basic components: (a) a baseline biological-chemical-physical study of present condition, (b) hazard evaluation based on knowledge of known potential pollutants entering the system and the estimated biological response to them, and (c) systematic and regular surveillance system (herein called a biological-chemical-physical monitoring system) designed to give early warning of impending harm.

Baseline Studies

Baseline studies are a particularly troublesome problem because most rivers or lakes, such as the Ohio River or Lake Erie, have little known about their original condition. That is, we have few substantive records of water quality preceding the onset of major societal use. Little is known about fish communities and even less about the types and quantities of lower organisms. Some information can be deduced from sediment cores and the like, but the reconstruction of the original condition is not an easy task. Nevertheless, data of this type may be capable of showing gross changes if not all of the subtle variability or minor fluctuations characteristic of most natural systems. Without question, we have under used this capability badly (i.e., information from sediment cores, etc.). For rivers and lakes not markedly altered or areas of these in reasonably decent condition, baseline surveys of this type should be carried out expeditiously before the opportunity is lost. Even for the systems now altered, it would be well to gather such evidence if only to insure that further degradation is documented if it occurs and to know what conditions existed at a specific point in time. Maintenance will not be effective unless present conditions are known. Such organizations as the Institute of Ecology are attempting to establish experimental ecological reserves which could be used as models for reference systems from which one could extrapolate to the original condition of other now damaged but ecologically similar systems. This type of information would, however, be more important for use in rehabilitation (the latter section of this paper). Environmental impact statements have been notably unsuccessful in establishing ecological baseline conditions as evidenced by the strong criticisms contained in a book edited by Reisa (in press). Since some of the parameters that might be examined to characterize biological integrity have been discussed already (Cairns 1977), they will not be repeated here. Other references for suitable methodologies may be found in the annual reviews of the _Journal of the Water Pollution Control Federation_ and such books as _Biological Methods for the Assessment of Water Quality_ (Cairns and Dickson 1973). Unfortunately, neither standard methods nor standard protocols for generating appropriate information now exists in sufficient quantity. However, a body of methodology widely used for this purpose is well known to professionals in the field, and one should get adequate results carrying out the basics properly.

Hazard Evaluation

Although papers on aquatic toxicity testing or bioassays were in the literature before World War II (e.g., Jones 1937), the emergence of the field of aquatic toxicity testing is marked by the appearance of the paper of Hart, et al. (1945) and subsequently modified for publication by Doudoroff, et al. (1951). Since that time, a number of different toxicity tests have appeared using a variety of organisms and evolving gradually (a) from batch testing to continuous flow, (b) from acute to chronic testing, and (c) from death as an endpoint to more sensitive parameters such as behavior. Readers unfamiliar with this literature may find representative citations in such books as _Water Quality Criteria of 1972_ (National Academy of Sciences 1974) or the annual summaries in the _Journal of the Water Pollution Control Federation_. More recently attempts have been made to couple information on environmental fate, distribution, transformations, partitioning, and so on of toxic materials to the concentration producing no adverse biological effects (e.g., Cairns 1978, Cairns, et al. 1978). These publications marked a shift in emphasis for at least part of the field of aquatic toxicology and represent an attempt to systematize the estimation of the probability of harm resulting from the use and production of various compounds. The American Society for Testing and Materials Special Technical Publication 657 just cited (Cairns, et al. 1978) contains three protocols which represent a means of systematizing the gathering of information for hazard evaluation as does the protocol produced by Cairns and Dickson (1978). All of the recent developments in the field represent attempts to produce order in programming the use of the vast array of methods

now available in the field of toxicity testing. Since there are now too many tests to perform for each compound, one must devise a means of selecting those that will produce the most useful information in determining the hazard or probability of harm. These generally are labeled protocols, and a comparison of those produced by different organizations in different countries has been made (Dickson, et al., in press).

Biological Monitoring

Biological monitoring is the systematic acquisition of biological data to be used in the maintenance of water quality or environmental quality generally. Almost any biological parameter (i.e., behavior, respiration, and so on) may be used, but the main requirement for this type of biological assessment is the speed with which the information is generated. The reason for optimizing time of information generation is to permit corrective action to be taken as soon as possible when deleterious effects are noticed or when the water quality deteriorates. As mentioned earlier, the environmental quality control systems are not basically different from industrial quality control systems in that they have: (a) sensors at critical spots throughout the system, (b) rapid generation of information and relay to a decision making unit, and (c) a decision making unit capable of taking immediate corrective action when permissible boundary conditions are exceeded. Industries have developed such quality control systems in producing products practically since the beginning of the industrial revolution. The operational concepts are no different for water quality management systems although they are not used widely now. The use of biological sensors is not, however, unknown since the king's wine taster and the canary in the mine are early versions of a biological sensor intended to be an early warning system of conditions unfavorable to human health. It is well established that water quality markedly affects the response of aquatic organisms to toxic conditions (for example, see some of the evidence in Water Quality Criteria of 1972 [National Academy of Sciences 1974]), and also water quality varies daily, seasonally, and regionally. Therefore, it is quite evident that a discharge which may be harmless under one set of water quality conditions may be lethal under others even though the effluent has not changed in either quantity or quality. Our present legislation based on the assumption that chemicals in effluents should not exceed certain concentrations can only be effective if these will not produce toxic conditions when introduced at any time or place regardless of water quality. As a consequence, if these laws are enforced rigorously, most effluents would be well below the concentrations producing no adverse biological effects most of the time. Stated another way, the natural assimilative capacity of a stream or lake is being underutilized most of the time without absolute assurance that very rare natural variations in water quality will not produce lethal conditions because there is no feedback of information about the biological response of the system to the discharge. In short, we are attempting in most of our regulatory actions to protect a biological system without direct evidence about the condition of the system being protected. Chemical evidence alone is not sufficient because: (a) there may be biological effects at concentrations that cannot be detected with present analytical capabilities, (b) chemical analyses are made on one component at a time and organisms react to the aggregate of compounds in their environment - this is particularly important since some compounds interact synergistically (i.e., their combined effect is greater than their individual additive toxicities), and (c) water quality markedly affects the expression of toxicity as already noted. Additional information on biological monitoring may be found in the book Biological Monitoring of Water and Effluent Quality (Cairns, et al. 1977).

REHABILITATION

Cairns, et al. (1977) edited a book containing case histories of damaged ecosystems returning to "normal" and were provided for both land and water. Since then, a follow-up symposium was held (Cairns, in press) in which the processes involved in recovery were discussed. Generally, recovery was thought to mean a return to either the original condition or a close approximation thereof. There are a number of difficulties in attempting to restore ecosystems to original condition, some of which follow. (1) The original condition for rivers long receiving societal waste and stresses may not be known in any substantive way. For example, it would be quite difficult to document the biological condition of the Hudson River at the time the basin was settled. (2) The ecological means of returning to a known prior condition are not understood, nor is it even certain that this is possible. (3) It well may be that the cost of restoring to original condition will be so great as to be considered unrealistic by most members of society, although a return of some of the greatly appreciated amenities may be considered a reasonal financial burden. (4) The presence of a man-made phenomenon for a

long period of time may genetically alter a species to the extent that restoration to a prior known condition may affect it unfavorably. Webster's Third New International Dictionary Unabridged (1968), page 1936, defines restoration as "a bringing back to or putting back into a former position or condition" and defines rehabilitation (page 1914) as "the restoration of something damaged or deteriorated to a prior good condition: improvement to a higher level or greater value." Upon reflection, it seems that society is more likely to accept the word rehabilitation in the sense that the system will be changed in such a way that it is of greater value (i.e., has more amenities) rather than the frightening proposition that society is going to try to return a damaged system to its original condition. The latter may be viewed as not technologically feasible and certainly will be viewed by many taxpayers as exorbitantly expensive. In this context, however, it is interesting to note that the book by John Doxat, The Living Thames (1977), is subtitled The Restoration of a Great Tidal River. Although the river has certainly not returned to original condition, many amenities have been restored.

Societal Resistance to Rehabilitation

Usually, proposals to restore the air of a city or the water of a drainage basin are met with cries of economic anguish from those who fear that the perceived benefits will be far outweighed by the costs. They may well be unable to visualize the benefits since these benefits may not be immediately available and, therefore, are unwilling to pay even a reasonable cost to achieve them. Society may offer resistance also in reaction to over zealous environmentalists who take a one dimensional view of every problem. The best counter to such arguments is the evidence that quite a number of ecosystems have been rehabilitated to a condition clearly superior to a previous condition with returned amenities appreciated sufficiently by society to be acknowledged generally. A number of case histories of this type may be found in Cairns, et al. (1977). Two examples are worth discussing in some detail.

Gameson and Wheeler (1977) have presented an extremely interesting history of the restoration and recovery of the Thames estuary. Pollution of the tidal Thames was a matter of concern from as early as 1620, although as late as 1766 large numbers of salmon were still being caught. During the first half of the 19th century, very serious degradation occurred. The records suggest that the last salmon was caught in 1833 and, that by 1850, all commercial fishing had ceased. In 1858 the odor originating from the Thames was so potent at Westminster that it caused the members of Parliament great distress since they were unfortunately close to the river. Doxat (1977) notes that at the beginning of the reign of Queen Elizabeth II there were virtually no fish in the tidal Thames, but, within recent years, 91 species have been found in the tideway. Plans for further improvement are being made, including the reintroduction of native oysters in Stangage Creek and the reestablishment of a salmon fishery. It is interesting that major rehabilitation was accomplished without causing a depression, and, in fact, there is evidence that the economic benefits resulting from the cleanup far outweigh the cost. The Thames water is extraordinarily heavily used for recreation. Even some reservoirs are being used for sailing and fishing. For such a small river, the various pressures upon it are truly enormous. Furthermore, many are in conflict; one could not have speedboat races and good fishing simultaneously. Nevertheless, a means of equitable distribution of uses seems to have been achieved. While there undoubtedly is some grumbling from special interests groups, during two visits in 1978, Cairns found general satisfaction with the present condition of the river and the return of various recreational amenities.

A somewhat similar case has been described by W. T. Edmondson (1977) who chronicles both the recovery of Lake Washington (located near Seattle) from eutrophication as well as the progressive deterioration of the lake that preceded the rehabilitation efforts. This deterioration produced sufficient and evident loss of amenities and unsatisfactory health and ecological conditions to unite the inhabitants of that region. This cleanup also seems to have been accomplished without an undue financial burden on the residents of the area and produced very dramatically improved amenities including improved recreation, improved esthetic conditions, and so on. Riley (1977) discusses similar rehabilitation of strip mined areas in Ohio.

These and a number of other case histories including those in a recent book by Holdgate and Woodman (1978) clearly illustrate (a) that rehabilitation is well within the technological and ecological grasp of society, (b) that it is not exorbitantly expensive, (c) that the public is capable of understanding the needs for rehabilitation if they are given adequate information and cost/benefit ratios, and (d) that the improvements in environmental quality are a source of civic pride and enjoyment and are clearly appreciated even by those

who make no personal use of the improved system. It is abundantly clear that public officials must have sufficient vision to see what might be done with polluted or degraded ecological systems and have the courage and dedication to see that what can be done is done.

Earlier Cairns (1976) proposed that an analysis of ecosystem vulnerability might include such characteristics as: (a) vulnerability to irreversible damage, (b) degree of elasticity[1] or the ability to recover from damage, (c) inertia, or the ability to resist displacement of structural and functional characteristics (i.e., ability to resist being placed in disequilibrium), and (d) resiliency, or the number of times a system can recover after displacement. It is proposed in that paper that elasticity is based on the following factors: (a) existence of nearby biologic epicenters (e.g., for river these might be tributaries) to provide organisms to reinvade a damaged system, (b) transportability or mobility of dissemules (dissemules might be spores, eggs, larvae, flying adults that may lay eggs, or another stage in an organism's life history which permits it either voluntarily or involuntarily to move to a new area), (c) condition of the habitat following pollutional stress, (d) presence of residual toxicants following pollutional stress, (e) chemical-physical environmental quality following pollutional stress, and (f) management or organizational capabilities for immediate and direct control of the damaged area.

The factors which determine ecological inertia are: (a) indigenous organisms accustomed to highly variable environmental conditions, (b) high structural and functional redundacy, (c) mixing and/or flushing capacity, (d) chemical characteristics such as presence of hard water which might be antagonistic to chemical toxicants, (e) proximity to a major ecological transitional threshold (e.g., from a cold-water to a warm-water fishery), and (f) regional management capabilities.

One might summarize the critical factors in elasticity in the rather simplistic Table 1, which is all that is presently warranted by the limited amount of evidence available. The critical factors for inertia are similarly given in Table 2.

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[1] Elasticity is used instead of resilience as used in the superb paper by Holling (1973) to differentiate between societal displacement and natural perturbations. Similarly, inertia is used instead of stability to indicate resistance to displacement as a result of societal or technological perturbations.

Resiliency, as defined in the paper, has been studied little, but one might hypothesize that a system cannot suffer an infinite series of displacements without eventually being seriously damaged. Alternatively, those ecosystems that suffer regular displacements will eventually be occupied by communities of organisms dependent on such displacements (e.g., Vogl, 1977).

The overriding question in all of this is whether one can actually acquire sufficient evidential "underpinnings" in order to make reasonably sound predictive models. The remainder of this paper is devoted to such a preliminary attempt on a portion of the material just discussed.

Stauffer et al. (in press) and Stauffer and Hocutt (manuscript in review) attempted to apply the inertia and elasticity indices to fish data collected from the Youghioheny River (Monongahela drainage) and Conowingo Creek (Susquehanna River drainage), respectively. To our knowledge, these are the only times that the concepts of inertia and elasticity have been examined in this fashion. It should be noted that in neither case were the data collected for these specific types of analyses. It is also worth noting that it is desirable to use more than one major taxonomic group. However, even these limitations do not preclude the possibility of a useful test of the hypothesis. The purpose of each study was to demonstrate how these concepts might be applied and to suggest possible modifications to the indices for practical application. Because of space restrictions, only key tables are reproduced herein and are referenced at the appropriate places. For the sake of simplicity and clarity, inertia and elasticity are discussed separately.

Calculation of Inertia Indices

In both cases, the drainage basin was divided into stream sections, each consisting of two or more sampling stations. Conowingo Creek was split into 4 sections, while the Youghioheny was divided into 15. Sampling stations were lumped together to form a particular section based on proximity to each other, similar physical (stream order, gradient, altitude) characteristics, or the formation of a defined subdrainage or tributary system. Additionally, main channel stations were divided into subsections based primarily on the presence of natural (i.e., waterfalls) or man-made (i.e., dams) barriers to fish dispersal.

Following the suggestion of Cairns (1976)

Table 1.--Rating the critical factors in elasticity

Factor	Rating 1	2	3
Existence of nearby epicenters	Poor	Moderate	Good
Transportability of dissemules	Poor	Moderate	Good
Condition of habitat	Poor	Moderate	Good
Presence of residual toxicants	Large amounts	Intermediate amounts	Small amounts
Chemical - physical water quality	Severe disequilibrium	Partially restored	Normal
Regional management capabilities	None	Intermediate	Strong

Table 2.--Rating the critical factors in inertia

Factor	Rating 1	2	3
Indigenous organisms accustomed to variable environment	Poor	Moderate	Good
High structural and functional redundancy	Poor	Moderate	Good
Mixing capacity	Poor	Moderate	Good
Chemical characteristics	Poor	Moderate	Good
Proximity to ecological threshold	Close	Moderate margin of safety	Substantial margin of safety
Regional management capabilities	Poor	Moderate	Good

and Cairns and Dickson (1977), each of the aforementioned parameters hypothesized to influence inertia was rated for each of the 15 stream sections using a three-point scale (1 = poor, 2 = moderate, and 3 = good) and was used to calculate an inertia index:

Inertia Index = a x b x c x d x e x f

Category a

Using the above system, a value of 2 was assigned to Category a for each stream section in both studies. This was chosen since streams in general have higher variable environmental conditions than ocean systems but are more stable than estuarine or tidal environments. Theoretically, Category a may have been omitted from the comparisons since it was the same for all sections; however, in order to make a rough approximation with the ranges suggested by Cairns and Dickson (1975), it was retained.

Category b

Category b is an evaluation of the structural and functional redundancy of the system. The calculation of values for this category was undoubtably the most involved. Using the checklist of fishes found in each section, structural redundancy was estimated using the families which were represented by more than one species. Using a checklist of fishes collected from each drainage, structural redundancy was estimated using the seven families which were represented by more than one species. The number of species in a particular stream section was divided by the total number of species from that family present in the respective drainage basin.

Tables 3 and 4 summarize the structural redundancy values for each stream section of Conowingo Creek and Youghioheny River, respectively. For example, in Section 1 of the Youghioheny, there were 2 of 3 possible species present from the family Salmonidae, 1 of the 2 from Esocidae, 5 of 21 from Cyprinidae, 1 of 6 from Catostomidae, 5 of 6 from Ictaluridae, 5 of 8 from Centrarchiadae, and 1 of 7 from Percidae. The mean structural redundancy for Section 1 was 0.362. Similarly, in Section 1 of Conowingo Creek, there were 7 of 15 possible species present from the family Cyprinidae, 2 of 2 from Catostomidae, 0 of 3 from Ictaluridae, and 0 of 4 from Centrarchidae. Similar calculations were made for each stream section in both studies.

Table 3.--Structural redundancy values used in calculating inertia indices for each stream section of Conowingo Creek (e.g., 7 of 15 cyprinid fish species occurred in Section 1)[1]

Families	Sections			
	I	II	III	IV
Cyprinidae (15)	7/15	9/15	15/15	8/15
Catostomidae (2)	2/2	2/2	2/2	1/2
Ictaluridae (3)	0/3	1/3	2/3	2/3
Centrarchidae (4)	0/4	1/4	4/4	2/4
Structural Redundancy	0.367	0.546	0.917	0.550

[1]Stauffer and Hocutt, in review.

For the purposes of both studies, functional redundancy was evaluated using only trophic level interactions. The trophic levels at which species interacted was determined using Carlander (1969), Scott and Crossman (1973), and the authors' knowledge of the food habits for these species. Functional redundancy values were tabulated using a method similar to that for structural redundancy (Tables 5 and 6). For example, in Section 1 of the Youghioheny River, there were 7 of 30 possible species from trophic level 1, 17 of 52 at level 2, 16 of 41 at level 3, 11 of 19 at level 4, and 2 of 4 at level 5. The mean functional redundancy for Section 1 was 0.406. It should be noted that many fish interacted at more than one trophic level.

The mean structural redundancy value and mean functional redundancy value for each stream section were averaged. The value of category b which was assigned to each stream section was based on this mean in the following manner: if the grand mean was between 0 and 0.2, a value of 1 was assigned; if it was between 0.2 and 0.4, a value of 1.5; if it was between 0.4 and 0.6, a value of 2; if it was between 0.6 and 0.8, a value of 2.5; and if it was between 0.8 and 1.0, a value of 3 was given. The values for category b for each stream section of Conowingo Creek and the Youghioheny River are given in Tables 7 and 8, respectively.

Category c

The value assigned to each stream section for category c was based on stream order, flow dependability, and flushing capacity. These data were obtained through the use of U.S. Geologic Survey topographic maps and familiarity

Table 4.--Structural redundancy values used in calculating inertia indices for each stream section of the Youghiogheny River (e.g., 2 of 3 salmonid fish species occur in Section 1)[1]

Families	Sections														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Salmonidae (3)	2/3	2/3	2/3	1/3	2/3	3/3	1/3	1/3	2/3	2/3	2/3	1/3	0/3	0/3	0/3
Esocidae (2)	1/3	1/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2	0/2
Cyprinidae (21)	5/21	7/21	6/21	18/21	6/21	6/21	5/21	6/21	7/21	11/21	6/21	9/21	11/21	10/21	9/21
Catostomidae (6)	1/6	2/6	2/6	5/6	1/6	2/6	1/6	1/6	1/6	2/6	2/6	2/6	4/6	2/6	3/6
Ictaluriade (5)	1/5	1/5	1/5	4/5	2/5	0/5	1/5	0/5	2/5	2/5	0/5	0/5	2/5	2/5	2/5
Centrarchidae (8)	5/8	4/8	5/8	7/8	5/8	3/8	3/8	2/8	3/8	6/8	3/8	5/8	8/8	4/8	4/8
Percidae (7)	1/7	3/7	4/7	6/7	0/7	0/7	1/7	1/7	1/7	3/7	3/7	3/7	3/7	1/7	2/7
Structural Redundancy	0.362	0.423	0.383	0.650	0.306	0.284	0.208	0.168	0.298	0.443	0.298	0.307	0.431	0.264	0.302

[1]Stauffer, et al. (in press).

Table 5.--Functional redundancy values used for calculating inertia indices for each stream section of Conowingo Creek (e.g., 7 of 18 fish species which interacted at trophic level I occurred in Section 1)[1]

Trophic Levels	Sections			
	I	II	III	IV
I (18)	7/18	10/18	17/18	10/18
II (26)	10/26	14/26	25/26	13/26
III (22)	7/22	11/22	21/22	11/22
IV (10)	2/10	3/10	9/10	3/10
V (2)	1/2	1/2	2/2	1/2
Functional Redundancy	0.358	0.479	0.952	0.471

[1]Stauffer and Hocutt, in review.

with the drainage basin. In general, the higher the stream order and flushing capacity, the higher the value. However, special circumstances also influence the value of this category. For example, Section 3 of the Youghioheny River was assigned a value of 3, mostly because water level in this section is controlled by low flow augmentation from the dam at the Youghioheny Reservoir. Other factors which may influence the values for this category include physical characteristics such as gradients which would affect flushing capacity. For example, in stream section IV of Conowingo Creek, the mean gradient was 28.4m/km; thus, the value of 3 was assigned. The respective values for each stream section for category c may be found in Tables 7 and 8.

Category d

A value of 1 was assigned to each stream section of the Youghioheny River for category d since none of the areas in the drainage are

Table 6.--Functional redundancy values used for calculating inertia indices for stream sections (1-15) on the Youghiogheny River, 1976[1]

Trophic Levels	Sections														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 (30)	7/30	10/30	10/30	26/30	7/30	6/30	8/30	8/30	10/30	14/30	6/30	10/30	18/30	13/30	11/30
2 (52)	17/52	21/52	21/52	43/52	14/52	13/52	13/52	12/52	17/52	28/52	17/52	21/52	29/52	19/52	18/52
3 (41)	16/41	18/41	18/41	32/41	13/41	9/41	11/41	9/41	14/41	24/41	13/41	17/41	21/41	14/41	13/41
4 (19)	11/19	10/19	10/19	14/19	12/19	5/19	6/19	4/19	7/19	10/19	6/19	7/19	11/19	7/19	5/19
5 (4)	2/4	3/4	1/4	2/4	1/4	0/4	1/4	0/4	1/4	2/4	1/4	1/4	2/4	1/4	1/4
Functional Redundancy	0.406	0.490	0.390	0.742	0.340	0.186	0.270	0.185	0.324	0.523	0.282	0.354	0.549	0.352	0.309

[1]Stauffer, et al. (in press).

Table 7.--Inertia indices (I = a x b x c x d x e x f) calculated for each stream section (1-4) in Conowingo Creek[1]

Stream Section	Index Categories						Inertia Index
	a	b	c	d	e	f	
1	2	1.5	1.0	3	2	1	18
2	2	2.0	2.0	3	2	1	48
3	2	3.0	2.5	3	2	1	90
4	2	2.0	3.0	3	2	1	72

[1]Stauffer and Hocutt, in review.

particularly well-buffered. Conversely, since the entire drainage basin of Conowingo Creek drains limestone rock and is consequently well buffered and, hence, antagonistic to toxic substances, a value of 3 was assigned to all stream sections.

Category e

Category e is an evaluation of how close the system is to a major ecological threshold. The closer the system is to such a threshold, the lower the value assigned. For the purposes of both studies, temperature was the only parameter considered. The assignment of values for this category is best explained by an example. Stream Section 9 (Youghioheny River) was given a value of 1 for this category. This section supports a native brook trout population. However, summer temperatures approach the lethal limits for brook trout; therefore, it was thought that this section was close to changing from a stream with "cold water fauna" to a warm water stream. The values assigned to this category for both drainages are presented in Tables 7 and 8.

Category f

The values given for category f for all sections in Conowingo Creek and Youghioheny River are discussed separately. To our knowledge, there is no basin management group which has established a monitoring program for

Table 8.--Inertia indices (I = a x b x c x d x e x f) calculated for each stream section (1-15) in the Youghioheny River[1]

Stream Section	Index Categories						Inertia Index
	a	b	c	d	e	f	
1	2	1.5	2.0	1	2	2	24
2	2	2.0	3.0	1	2	2	48
3	2	1.5	3.0	1	3	2	54
4	2	2.5	3.0	1	3	2	90
5	2	1.5	1.5	1	2	2	18
6	2	1.5	2.5	1	2	2	30
7	2	1.5	2.0	1	2	2	24
8	2	1.0	2.0	1	2	2	16
9	2	1.5	2.0	1	1	2	12
10	2	2.0	2.0	1	3	2	48
11	2	1.5	2.5	1	2	2	30
12	2	1.5	2.0	1	3	2	36
13	2	2.0	2.0	1	3	2	48
14	2	1.5	1.5	1	3	2	27
15	2	1.5	1.5	1	3	2	27

[1]Stauffer, et al. (in press).

Conowingo Creek. Therefore, a value of 1 was assigned to category f for each area. However, because mining occurs throughout the Youghioheny River basin, water quality is monitored at several stations. Additionally, the respective Trout Unlimited chapters have a loose-knit monitoring program. Although these monitoring programs are not as sophisticated as a drainage basin management group might organize, they do provide the basis for an early warning monitoring system. Therefore, a value of 2 was assigned for each stream section in the basin. Tables 7 and 8 give the calculated inertia indices for each stream section in Conowingo Creek and Youghioheny River, respectively.

Calculation of Elasticity Indices

In contrast to the calculation of the inertia indices, only three of the categories suggested by Cairns and Dickson (1975) can be used to calculate a recovery index: a: existence of nearby epicenters for providing organisms to reinvade a damaged ecosystem, b: mobility of any dissemules of the organisms present, and f: management of organizational capabilities for immediate control of the damaged area. A stress must first occur or one must have information on which to estimate the type of stress before categories c (condition of habitat following stress), d (presence of residual toxicants), and e (chemical-physical environmental quality after pollutional stress) can be used. This could be done if one knew the probable discharge characteristics of a manufacturing plant. Therefore, the index measures the potential of a particular section to recover where Elasticity Index = a x b x f. Tables 9 and 10 give the calculated elasticity indices for each stream section in Conowingo Creek and Youghioheny River, respectively.

Table 9.--Elasticity indices (E = a x b x c x d x e x f) for each stream section (1-4) of Conowingo Creek (variables c, d, and e omitted from calculation)[1]

Stream Section	Index Categories a	b	f	Elasticity Index
1	2	2	1	4
2	3	2	1	6
3	1	2	1	2
4	3	2	1	6

[1]Stauffer and Hocutt, in review.

Table 10.--Elasticity indices (E = a x b x c x d x e x f) for each stream section (1-15) in the Youghioheny River (variables c, d, and e omitted from calculation)[1]

Stream Section	Index Categories a	b	f	Elasticity Index
1	1.5	2	2	6
2	2.0	2	2	8
3	2.0	2	2	8
4	3.0	2	2	12
5	1.0	2	2	4
6	1.5	2	2	6
7	1.0	2	2	4
8	1.0	2	2	4
9	2.5	2	2	10
10	1.5	2	2	8
11	1.5	2	2	8
12	1.5	2	2	8
13	2.0	2	2	8
14	2.0	2	2	8
15	2.0	2	2	8

[1]Stauffer, et al. (in press).

Category a

Category a is a measure of nearby epicenters from which invading species (i.e., potential colonizers) can originate should a stress occur; values for this section are based on the proximity of other sections which have a diverse fauna. For example, the farthest downstream section (section 4) in the Youghioheny was assigned a value of 3 for this category. If a change in the structure or function occurred within this area, fauna could reinvade the section from two tributaries which contained diverse fauna and from the main-channel Monogahela River. On the other hand, stream section 1 of the Youghioheny River (most upstream area of the main channel) was assigned a value of 1.5. If the fauna were destroyed, reinvasion would be possible only from small tributaries which had depauperate faunas. Migration of fishes from lower stream sections would be prevented by the presence of a major waterfall. Using similar reasoning, values for category a were assigned to each stream section for both Conowingo Creek (Table 9) and Youghioheny River (Table 10).

Category b

A value of 2 was assigned to each section for category b for both drainages. Although fish are relatively mobile organisms, they lack an aerial stage like most aquatic insects; therefore, stream sections were not assigned a value of 3.

Category f

Because some monitoring programs are in progress (see section on inertia), a value of 2 was assigned to each stream section for category f of the Youghioheny River. On the other hand, since there are no management or organizational capabilities for immediate control of Conowingo Creek (with the possible exception of the Pennsylvania Fish Commission), a value of 1 was assigned for each stream section.

Discussion

It should be noted that functional redundancy was based only on trophic level interaction. Certainly as more life history information becomes available for different fish species, other parameters can be included in the analysis. Perhaps each life stage of the species present should be identified, counted, and analyzed separately. Because of the relatively few taxa (27-Conowingo Creek; 55-Youghioheny River) present, structural redundancy was calculated by counting the number of species present in a particular family. If a more diverse fauna existed, or another major taxonomic category was used (e.g., aquatic insects or protozoans), it might be more applicable to count the number of species in a particular genus. These indices should be calculated using an array of different phyletic groups and applied to various ecosystems before a "best method" is determined.

Additionally, one might argue that both structural and functional redundancy are important enough to warrant separate categories. However, this raises the question of why structural redundancy values are included any place in the analysis. In both studies, structural redundancy was interpreted as being related to taxonomic groupings. Since an organism's niche is species specific and the niche is intimately tied to function, as interpreted by Schoener (1974), structural redundancy implies functional redundancy! Our interpretation for this case study may be somewhat narrow since only fish were studied. For example, several taxonomically dissimilar species may produce glycolic acid thus fulfilling similar functions in a microbial community. Clearly they could also be in distinct niches. Even this brief exercise has shown the need to approach both structural and functional redundancy differently for the major taxonomic groups (e.g., fish and algae).

It should be emphasized that the elasticity index is a measure of the potential of the system to recover should a displacement occur. The practical use of the elasticity index is limited at present by the paucity of information on dispersal rates of fishes and other aquatic organisms. As information of this type becomes available, this index should become more useful; however, it should be remembered that speed of locomotion is not necessarily correlated with ease of dispersal (Udvardy 1969). Even with the inherent difficulties in the calculation of an elasticity index, a particular relationship between inertia and elasticity emerges. In Conowingo Creek, the area with the highest inertia index (Section 3) had the lowest elasticity index. Although this relationship does not always exist (as evidenced by data from the Youghioheny River), a management decision might be made from this evidence to protect stringently those sections with high inertia and low elasticity from which recolonization of other areas with greater elasticity and lower inertia could occur if necessary.

It should be noted that all of the parameters suggested by Cairns (1976) and Cairns and Dickson (1977) can be used in the calcu-

lation of the inertia index. Additionally, since an inertia index can be calculated without the occurrence of a stress, it provides more information upon which to base management decisions than the elasticity index unless the potential pollutants that might enter the system are reasonably well defined.

Before this system can be fully evaluated, these types of analyses must be applied to various ecosystems using different phyletic groups (e.g., microbial species, macroinvertebrates, and so on). Fish were used in both cases because data were available, but more importantly, because (a) they occupy the top of the food chain in most stream systems, and, as such, their presence indicates the presence of other phyletic groups, (b) throughout their development from larvae through adult, they pass through most, if not all, trophic levels above the primary producer stage, (c) taxonomically, fish have been well-studied; hence, accurate identifications can be made easily and quickly without the aid of sophisticated equipment, and (d) there is generally more information available on their life history than is available for other groups so the relationship between structure and function is easier to compare than for other groups.

CONCLUSIONS

It is possible to both maintain and rehabilitate riparian habitats in the eastern United States with existing methodology. Water quality can be maintained by using a combination of biological assessment and biological monitoring to provide information feedback about the biological conditions of the system being protected. Few such efforts are in place at this time. Biological assessment must be done in concert with chemical-physical monitoring or the information base will not be adequate for sound decisions.

The rehabilitation of the Thames River provides compelling evidence of what can be done with present methods without undue economic hardship. Understanding the recover process more fully should make rehabilitation less costly and require less time. Maintenance is both ethically and economically more desirable than waiting until an ecosystem has been damaged before exercising stewardship.

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Revegetating the Riparian Floodplain for Wildlife[1]

Bertin W. Anderson, Robert D. Ohmart, and John Disano[2]

Abstract.-- A two-phased study of riparian vegetation-wildlife interactions was begun in 1973 in the lower reaches of the Colorado River. During the first phase, efforts were directed at discovery of vegetative characteristics to which birds were responding. This investigation led to the discovery that horizontal and vertical foliage diversity and presence of cottonwood and/or willow trees were positively correlated with the number of species in an area. Bird densities were enhanced by increased horizontal foliage diversity and presence of mistletoe, quail bush, and ink weed. Presence of salt cedar was found to contribute negatively to both the number of species and densities. A model has been developed revegetating riparian areas for the enhancement of wildlife from the 5-year data base on vegetative-wildlife interactions. Data relative to growth and survival rates of cottonwood, willow, honey mesquite, and quail bush are presented. Monitoring of wildlife present on the revegetation site for one year led to the discovery that growth of annuals is important for attracting large wintering populations the first winter after planting.

INTRODUCTION

Riparian vegetation along the lower Colorado River has a long history of disturbance by man (Ohmart, *et al*. 1977), and removal of this riparian growth is continuing at a high rate today. About 1200 ha per year are being removed. Combined with habitat loss, about 50 years ago the introduced salt cedar (*Tamarix chinensis*) became an important invader of the river valleys in the southwest (Robinson 1965), frequently at the expense of indigenous riparian vegetation. Salt cedar has been found to be rather poor wildlife habitat (Anderson *et al*. 1977a, b, Cohan *et al*., this symposium) and for that and other reasons it is an undesirable replacement for indigenous species. In 1973 we began conducting a two-phased research program directed toward eventually manipulating vegetation for the enhancement of wildlife. The first phase of the study was concerned with discovering some of the vegetative parameters associated with large avian densities and diversities. (Birds will receive the main focus of attention in this report.) On the basis of this information we developed a model designed to maximize wildlife use. The second phase is ongoing and is directed at implementing the model and monitoring the results. In this report we will summarize the data concerning the vegetative parameters we found to be correlated with avian densities and diversities along the Colorado River. Next we will present a model, based on the 5-year field data, designed to enhance wildlife. Finally, we will summarize vegetative and faunal data collected after monitoring the revegetation effort for one year.

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METHODS

Communities were classified according to predominant vegetation and vertical configuration (structure). This led to the recognition of 23 community-structural types (for details see Anderson et al. 1977a). Two to eleven transects, each 800 to 1600 m long were established in each community-structural type. Birds were censused (Emlen 1971) two or three times each month from December 1974 to August 1978. Exigencies affecting censusing and ways in which we dealt with them have been discussed elsewhere (Anderson and Ohmart 1977).

The annual cycle was divided into seasons based on changes within the bird community. These seasons were: winter (December through February), spring (March-April), early summer (May through July), late summer (August-September), and fall (October-November).

Foliage height diversity (FHD) was determined using the formula $-\Sigma p_i \ln p_i$ after obtaining relative volume estimates along each transect using the board technique (MacArthur and MacArthur 1961). In the equation p_i represents the proportion of total volume in the ith layer. Patchiness or horizontal foliage diversity (HFD) was developed from our field data and is as follows:

$$\left[\frac{\sum_{i=i}^{K} \sum_{j=1}^{n} V^2 i\, j - \frac{(\sum_{j=1}^{n} V_{i\, j})^2}{n}}{n-1} \right]$$

Where V_{i_j} represents the foliage volume obtained (from the board technique) at vertical level i at station j, k is the number of levels and n represents the number of stations. Each station represented a unit 150 m long on each side or a grain size of about 0.08 ha. In practice we assumed four vertical layers in the vegetation (0.15 m to 0.6 m, 1.5 m to 3.0 m, 4.5 m to 6 m, and >7.5 m). This method has been presented in greater detail elsewhere (Anderson and Ohmart 1978a).

All trees and shrubs within 15 m of either side of the transect for the entire length were counted directly to obtain densities of each species along the transect. The totals for each transect within a community-structural type were then averaged for value for that community-structural type.

In summary, within each community-structural type (23 in all) we established two to 11 transects. From these we obtained the average vertical and horizontal diversity in the vegetation (FHD and HFD, respectively) as well as the number of each species of tree and shrub present. Since bird censuses were conducted on a monthly basis on each transect, we were able to study interrelationships between avian population parameters and various vegetative parameters on a seasonal basis.

RESULTS

First Phase

Numbers of species and HFD

Number of species was positively correlated ($p<0.05$) with HFD in eight of ten seasons (fig. 1). This correlation was consistently greater than the between number of species and any other single vegetative parameter considered. The correlation was not significant in winter 1975-1976 or spring 1976. Lack of correlation does not appear to fit any pattern and may represent chance variation.

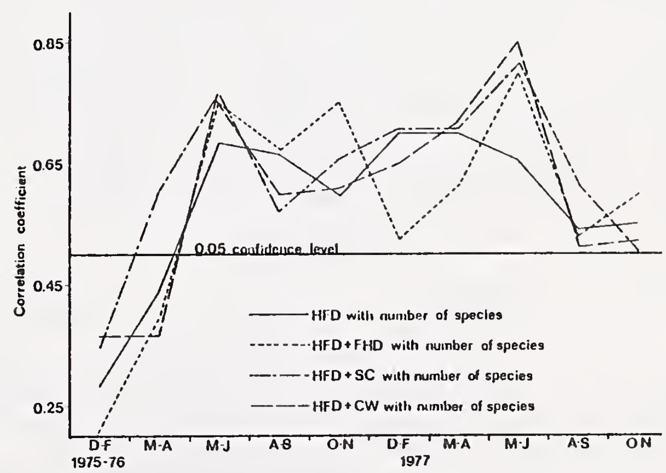

Figure 1.--Correlations between numbers of species present and various vegetation parameters.

Numbers of species and FHD

FHD was positively correlated with the number of species present. To evaluate the influence of FHD on numbers of species a multiple regression analysis was conducted to test the combined effect of HFD and FHD on the number of species. This revealed that in seven of ten cases the correlation between HFD and number of species was improved when FHD was considered (fig. 1). Variation seemed to follow a pattern; FHD had slight

negative effects in winter and spring, nearly no effect in late summer, and had a relatively large additive effect in early summer.

Number of species and presence of salt cedar

The correlation between number of avian species present and number of salt cedar trees in the area was negative. When adjusting, through multiple linear regression, for the amount of salt cedar present the correlation between number of species present and HFD was improved in eight out of ten seasons (fig. 1). The variation seemed to fit a pattern; there was a consistent improvement in HFD-species correlations in spring, early summer, and winter when the amount of salt cedar was considered (fig. 1). Salt cedar appeared to have less of a bearing on the correlation in late summer and fall, but results at these times of year were inconsistent. Adjusting for salt cedar appeared to be most important in early summer.

Numbers of species and the presence of cottonwood and/or willow

The presence of cottonwood (Populus fremontii) and/or willow (Salix gooddingii) was slightly positive. When HFD-species correlations were adjusted to reflect the presence of these trees the correlation was improved five out of ten seasons. Deviations seemed to fit a pattern; presence of cottonwood and/or willow had a relatively large additive effect in early summer and a negative effect in late summer. Deviations at other times of year were inconsistent.

Analysis of variance

Although a significant correlation indicates a straight line relationship between HFD and number of species, it offers no interpretation relative to the extent of the difference between the number of species in areas with large and small HFD's. An analysis of variance indicates whether or not the observed variance in number of species is about what is expected if the variation is random or whether it is systematically associated with some variable. We used a two-way analysis of variance to simultaneously test the influence of community types and HFD on the number of species present in early summer 1976 and 1977. The results (Table 1) varied; in 1976 the variation was associated with only HFD ($p<0.05$), but in 1977 both HFD and plant community were important ($p<0.025$ and $p<0.01$, respectively) in explaining the variance. This suggests that not only is there a significant straight line relationship between the number of species present and HFD in the area, but that the resulting variance is great enough to be attributable to something other than chance and may therefore be biologically important. In Table 1 the mean number of species by rows demonstrates the contribution made by various plant communities; that of columns indicates the contribution of HFD. In both years cottonwood-willow communities and areas with higher HFD's had a greater average number of species.

Effect of quail bush on number of species and densities

The value of quail bush (Atriplex lentiformis) was evaluated by studying areas which were vegetatively similar except that experimental plots contained quail bush and control plots did not (Table 2). Although the number of avian species in control and experimental plots were nearly equal, there were a larger number of species which reached higher ($p<0.05$) densities in experimental plots in three of four seasons studied (Table 3). In winter and summer, for both years, there were more birds ($p<0.001$) on experimental plots (Table 4).

Eight species in winter and four in summer accounted for most of the disparities in populations between experimental and control areas (Table 4). The combined total of these species was greater ($p<0.001$) on experimental plots, whereas total populations of other birds in control and experimental plots were not different ($p<0.1$).

HFD and bird densities.

We found that densities of birds in a given layer was directly related to horizontal diversity of vegetation at that level. From regression equations (Table 5) it can be seen that layers do not contribute equally to densities. For example HFD of 0.1 for the layer 0.15 to 1.5 m would contribute a density of 33 birds per 40 ha, but a similar HFD at 4.6 to 7.6 m would add about 119 birds. Theoretically an HFD of 0.1 at 7.6 m would add 916 birds to the area, but we cannot confirm this from field data because we have been unable to find areas with such a large diversity at that level.

Trees with mistletoe and fruit-eating birds

Over a period of three winters there were more fruit-eating birds ($p<0.05$) during the last two winters in areas where more trees were parasitized by mistletoe

Table 1. Results of two-way analyses of variance showing effect of dominant vegetation (rows) and HFD (columns) for two years in the lower reaches of the Colorado River.

Community Types	Number of Species				Row Means: Number Species	Row Means: HFD
1976						
Cottonwood-willow	35	21	18	21	23.5	0.062
Honey mesquite	25	21	22	21	22.3	0.073
Screwbean mesquite	23	23	21	11	19.5	0.055
Salt Cedar	18	18	21	18	18.8	0.060
Mean number of species, columns	25.3	20.8	20.5	17.8		
Mean HFD, columns	0.136	0.081	0.038	0.022		
F columns = 3.5, df = 3,9, p = 0.05						
F rows = 1.12, df = 3.9, p>0.05						
1977						
Cottonwood-willow	35	29	28	23	28.8	0.062
Honey mesquite	31	25	24	23	25.8	0.073
Screwbean mesquite	26	28	23	21	24.5	0.062
Salt cedar	24	18	20	21	20.8	0.065
Mean number of species, columns	29.0	25.0	23.8	22.0		
Mean HFD, columns	0.151	0.087	0.044	0.011		
F columns = 6.0, df = 3,9, p =< 0.025						
F rows = 7.4, df = 3,9, p = <0.01						

Table 2. Comparative vegetative characteristics of plots with (experimental) and without (control) quail bush.

	Vegetative Characteristics			Horizontal Foliage Diversity				
				(Layers*)				
	Transects (km)	FHD	Relative Volume	1	2	3	Total	Quail Bush (N/40 ha)
Controls	14.1	0.919	0.529	0.022	0.025	0.008	0.055	200
Experimental	4.9	0.930	0.491	0.011	0.027	0.022	0.060	0

* The fourth layer was absent

Table 3. Total number of species and densities on plots with (experimental) and without (control quail bush.

	Number of Species			Number of Species More abundant	
	Experimental	Control	P	on Experimental Plots	P
Number of Species					
Dec-Feb 1976-77	32	33	NS	23	0.025<p>0.01
Dec-Feb 1977-78	35	38	NS	25	0.10 <p>0.05
May-Jul 1976	30	3k	NS	21	0.05 <p>0.025
May-Jul	31	32	NS	26	p>0.001
Number of birds/40 ha					
Dec-Feb 1976-77	294	123	0.001		
Dec-Feb 1977-78	303	157	0.001		
May-Jul 1976	181	117	0.001		
May-Jul 1977	219	149	0.001		

Table 4. Species which showed consistent population differences in plots with (experimental) and without (control) quail bush.

	Number/40 ha							
	Dec-Feb				May-Jul			
	1976-77		1977-78		1976		1977	
Species	Exp	Cont	Exp	Cont	Exp	Cont	Exp	Cont
Abert Towhee (Pipilo aberti)	22.8	23.0	7.0	34.3	16.6	32.5	12.7	--
Blue Grosbeak (Guiraca caerulea)	--	--	--	--	7.9	4.2	8.0	5.0
Blue-gray Gnatcatcher (Polioptila melanura)	2.9	1.6	10.0	1.8	--	--	--	--
Brown-headed Cowbird (Molothrus ater)	--	--	--	--	24.5	12.1	17.8	9.3
Crissal Thrasher (Toxostoma dorsale)	7.9	2.0	6.1	2.7	8.3	3.4	10.4	3.8
Gambel Quail (Lophortyx gambelii)	12.1	7.0	5.4	2.0	25.0	20.4	17.7	13.4
Orange-crowned Warbler (Vermivora celata)	6.7	2.0	17.2	4.5	--	--	--	--
Ruby-crowned Kinglet (Regulus calendula)	31.1	13.8	51.2	29.2	--	--	--	--
Verdin (Auriparus flaviceps)	13.3	5.2	23.0	11.4	25.6	17.6	38.3	18.5
White-crowned Sparrow (Zonotrichia leucophrys)	118.8	25.3	61.2	15.9	--	--	--	--
Total	215.6	64.5	197.1	74.5	125.6	74.3	124.7	62.7
Probability of difference being due to chance	<0.001		<0.001		<0.001		<0.001	
Total population of other birds	78.4	58.5	105.9	82.5	55.1	42.7	93.4	86.3
Probability of difference being due to chance	0.1>p>0.05		0.1>p>0.05		0.5>p>0.1		0.9>p>0.5	

Table 5. Regression equations used to predict bird densities in various layers of vegetation along the lower Colorado River.

Layer Height (m)	Regression Equation used for Predicting Densities	No. of Species assoc. w/layer	Correl. Coef. (r)	P
0.15-1.5	272.5X + 6.21	11	0.829	<0.005
1.5 -4.6	532.8X +43.5	13	0.786	<0.01
4.6 -7.6	555.5X +62.7	10	0.831	<0.005
7.6	8,831.0X +33.4	19	0.792	<0.01

(Phoradendron californicum) (fig. 2). The correlation was weakest in 1974-75, a relatively harsh winter when many of the mistletoe berries froze. The freeze was not consistent, however, being more severe in areas closer to the river (Anderson and Ohmart 1978b). Mistletoe berries and fruit-eating birds were largely absent in summer.

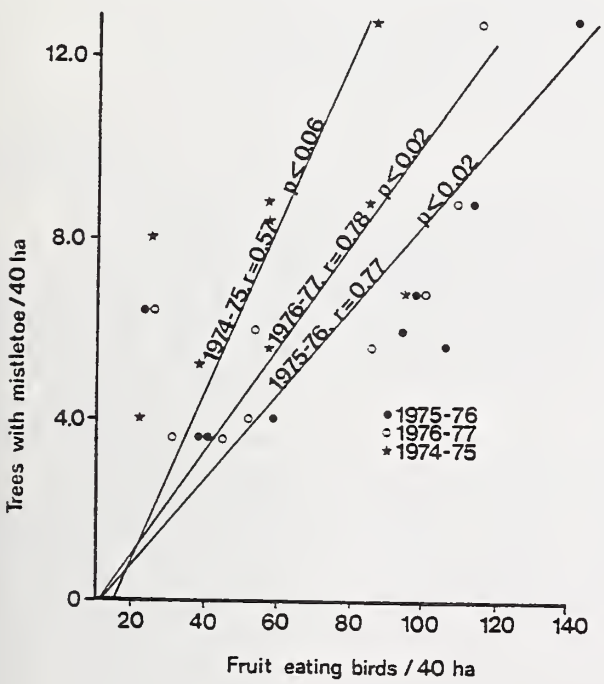

Figure 2. Correlations between number of trees with mistletoe and the number of fruit-eating birds.

Ink weed and the Sage Sparrow

Greater numbers ($p<0.03$) of Sage Sparrows (Amphispiza belli) were consistently found in winter in areas with greater numbers of ink weed shrubs (Suaeda torreyana) (fig. 3). Sage Sparrows are winter visitors.

Summary and conclusions

Among the vegetative parameters considered, relatively large HFD's seemed to be the most important vegetative parameter relative to the attraction of a large number of avian species. However, areas with relatively large HFD's would be further enhanced if there was a relatively large vertical diversity (FHD), and if there were substantial numbers of cottonwood and/or willows. The area would benefit further from removal of salt cedars. (Details concerning the negative impact of

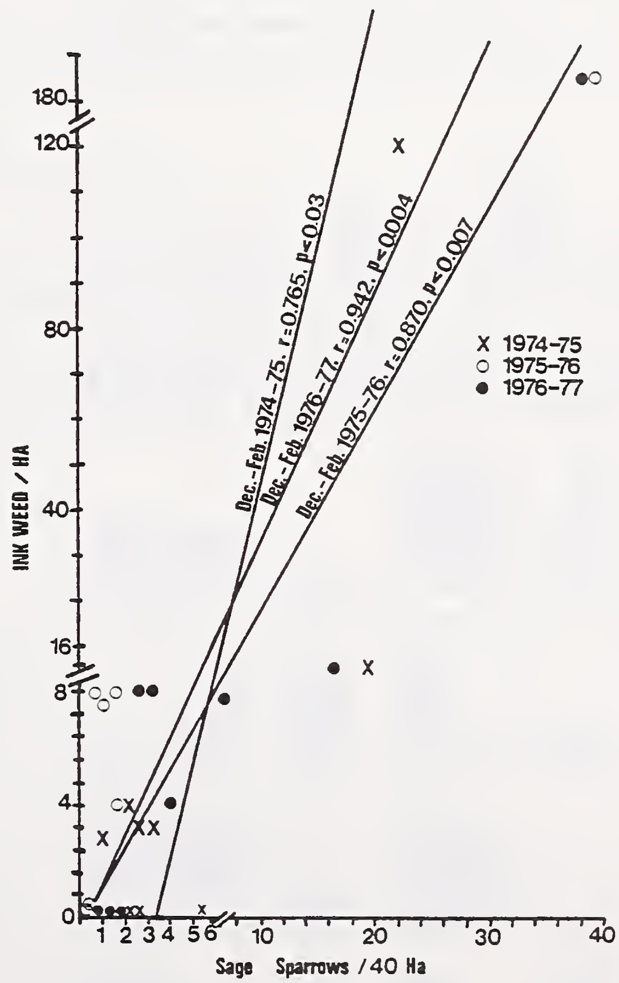

Figure 3. Correlation between amount of ink weed and number of Sage Sparrows.

salt cedar have been presented elsewhere Cohan et al., this symposium). Additional species were added to a community in winter if trees were parasitized by mistletoe. In

the Colorado River Valley mistletoe infects honey mesquite (Prosopis velutina) almost exclusively. Thus in this region honey mesquite must be planted to maximize the chances for mistletoe occurrence. Avian densities, as well as diversities, will theoretically increase significantly if there is diversity in the horizontal dimension in all four layers of the vegetation. In addition, if quail bush and ink weed are relatively abundant in some of these patches, densities of at least nine bird species in summer and six in winter will be further enhanced.

REVEGETATING A CLEARED AREA

A revegetation design was developed for an area (fig. 4) after salt cedar was cleared; the design was such to maximize FHD and HFD. In addition, valuable trees such as cottonwood and willow and shrubs such as quail bush and ink weed were included. Honey mesquite was also included and we expect mistletoe to invade these trees naturally. In this regard we are also experimenting with artificial infestations.

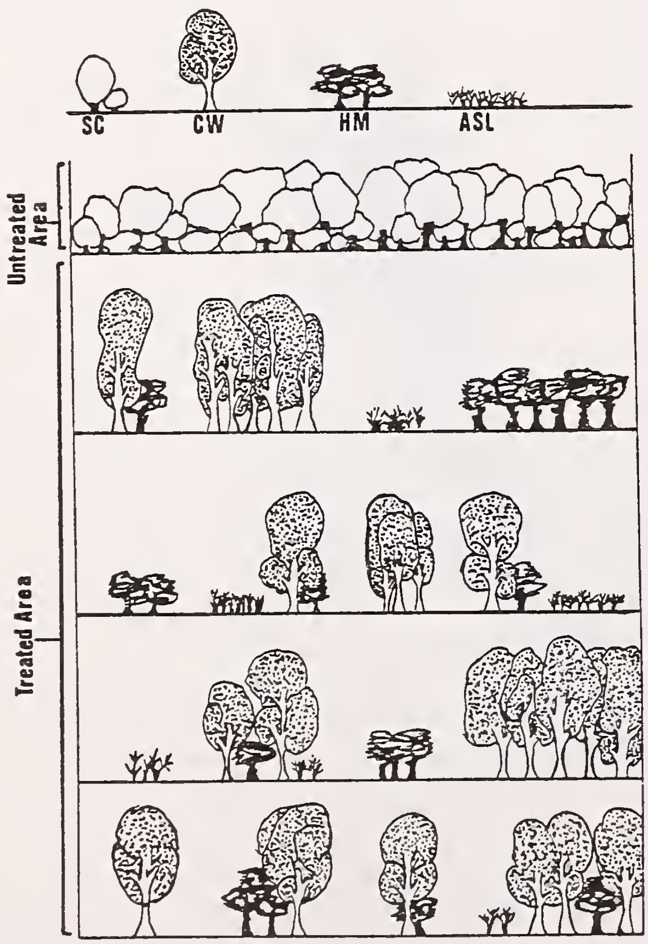

Figure 4. Schematic illustration depicting vegetative diversity in a model designed for enhancement of wildlife. Note three fire lanes to be maintained in the area.

The model is designed to maximize vertical and horizontal foliage diversity and to include plant species of proven value to wildlife. The untreated salt cedar is depicted at the top of the illustration. After clearing the salt cedar it will be replaced with vegetation as per the model.

The grain size that we refer to as patches is about 0.08 ha in extent (Anderson and Ohmart 1978a). Our revegetation site includes roughly 30 of these plots. We anticipate that HFD will be between 0.25 and 0.50. If the upper limit is attained,the area theoretically at maturity would support the maximum number of species present in the Valley at densities of at least 0.5/40 ha. For early summer this would amount to 53 species. Since the top layer (>7.5 m) had the most species (19), most of which show a high fidelity to that layer, it seemed important to design this layer for maximum diversity. The two middle layers collectively have 21 species, most of which will occur even if patchiness in these layers is not great. Therefore, we have not devoted as much effort to maximizing HFD in these layers. Nonetheless the anticipated HFD for these layers (0.035 to 0.100) is adequate to attract relatively large populations of the species associated with these layers. Similarly HFD at the lowest level was sacrificed in order to ensure a relatively large HFD at the highest level because species associated wtih vegetation at or near ground level generally have small populations (Table 6). As with the middle layers we anticipate adequate HFD values (0.035 to 0.10) to include all of the species associated with that layer. Since all species enhanced by the presence of quail bush (Table 4) were also associated with the lowest three layers we hope to more than compensate for any loss in density because of the somewhat reduced HFD's by having a relatively large amount of quail bush on the site. In addition, fruit-eating species will be attracted to the area when mistletoe begins infecting the honey mesquite. Additonal information concerning plot diversity is provided in Table 6.

Results of the Second Phase

During the first year's experience in re-establishing native vegetation we have acquired sufficient data to warrant a summary of our results so that land managers might benefit from it. We monitored changes not only in the vegetation but also in portions of the fauna (birds, rodents, rabbits, and insects). This information has given additional insight into how to proceed with manipulation of vegetation for wildlife enhancement.

Table 6. Additional information concerning the diversity of site planned for revegetation after clearing salt cedar. The area has a total of 30 subplots each with an area of 0.08 ha.

Number of subplots dominated by	
Cottonwood-willow	11
Honey mesquite	7
Quail bush	9
Number of subplots with	
Cottonwood-willow present	21
Honey mesquite present	23
Palo verde present	13
Quail bush present	17
Only cottonwood and/or willow	2
Only quail bush	1
Only honey mesquite	2
At least ¼ bare soil	19
No bare soil	11
Number of plots immediately adjacent	
Vegetation dominated by salt cedar	16
Road and main irrigation canal	6
Small ponds	3
Agricultural situation	1

Vegetation

We acquired growth and mortality rates for palo verde (Cercidium floridum), willow, cottonwood and honey mesquite. A limited amount of information was acquired for quail bush and salt bush (Atriplex canescens).

Palo verde trees

Several palo verde trees voluntarily germinated in two separate locations on the revegetation site in September 1976. In one of these locations (site 1) we began watering trees in mid-May 1977. A few of these were not watered and served as controls. All trees were measured (height, crown diameter) in mid-May.

In the other area (site II) watering was not initiated until June and measurements were not taken until late June. A small number of controls were left unwatered. In both cases the controls grew slightly but significantly ($p<0.01$) (Table 7). The group receiving water in May grew to nearly 1.5 m tall and over 4 m in crown diameter. The unwatered trees in site I grew significantly less in height and crown diameter than the unwatered trees in site II.

Willow trees

We planted 23 native Goodding willows which had been started in the greenhouse from cuttings which measured about 30 cm long and 2 to 3 cm in diameter. These trees did not grow significantly in height by the end of the growing season (Table 7), but increased from about 15 cm to about 76 cm in crown diameter.

Cottonwood

Native cuttings were started in a greenhouse in February 1977, and measured 30 cm long and 3 cm in diameter. They were field planted in loam and very sandy soil in late June and early July 1977. There was no difference in vertical growth; those in sand and loam both grew from about 120 cm to nearly 170 cm. Those planted in sand grew 19 cm less in crown diameter than those planted in loam (Table 7). Those in loam grew from about 15 cm to 100 cm in crown diameter; those in sand grew slightly, but significantly ($p<0.05$) less.

Honey mesquite

Honey mesquite seedlings started in February in the greenhouse were planted in late June 1977. At about this same time several honey mesquite seeds deposited on the area in cow dung began germinating. At the

time that measurements were made those which volunteered from cow dung were shorter than the greenhouse stock. Nonetheless, by the end of the growing season, those started in the greenhouse were significantly shorter than those which germinated from cow dung (Table 7).

Table 7. Growth (cm) of four tree species on the revegetation site in 1977. Two standard errors of the mean are in parentheses.

	Height				Diameter			
Species	N	Initial	N	Final	N	Initial	N	Final
Palo Verde								
Unwatered Site I	17	16.3(3.3)	23	25.4(3.3)	17	5.3(0.3)	19	20.6(4.8)
Unwatered Site III	19	22.6(7.1)	27	50.0(15.0)	19	7.8(0.8)	19	45.7(8.9)
Watered, begun May Site III	63	20.3(2.5)	80	132.3(10.2)	63	7.6(1.0)	61	127.0(12.7)
Watered, begun June Site I	91	17.8(2.5)	89	80.3(6.6)	72	16.3(0.5)	68	128.3(24.1)
Willow	23	133.4(12.2)	23	139.2(20.8)	17	16.3(2.5)	17	75.7(22.9)
Cottonwood								
Loam	43	125.5(7.6)	43	161.8(10.2)	33	15.0(2.5)	31	98.6(14.7)
Sand	31	125.5(8.1)	31	164.1(11.2)	27	13.5(0.8)	30	81.3(11.4)
Honey Mesquite								
Started in greenhouse	53	43.7(6.9)	53	92.3(17.3)	27	5.1(1.0)	27	44.7(13.5)
Volunteers started from seed	25	25.4(10.2)	25	113.8(16.3)	23	4.1(1.0)	23	50.8(13.2)

Growth rates

Growth rates (Table 8) for willow and unwatered palo verde trees were almost negligible, while palo verde watered from mid-May and honey mesquite which germinated from seed grew in height at a rate of over 60 cm per 100 days. Palo verde and cottonwood acquired the greatest crown diameter (30 to 90 cm) per 100 days.

Root growth

Root growth to a depth of about 2 m was attained for 40 cottonwood trees after four months of watering at a rate of about 150-200 liters per day. This was sufficient for the roots to either reach the water table or a level where there was permanent soil moisture. These trees survived the second summer with no additional watering. The soil in which these trees were planted was unlayered for at least 1.5 m to 2 m. Another 20 trees were planted in soil in which there was distinct change in soil texture at 0.6 to 1 m. When watering the second summer was stopped, none of these trees survived.

When water seeping downward from the surface encounters a different soil texture, it begins spreading laterally rather than continuing downward. Since roots follow water they also tend to spread laterally. Because desiccation of bare soil in our area is nearly 100 percent to a depth of up to 1 m, it was not suprising that these trees died when watering ceased. The effect due to soil layering can be avoided by using a soil auger to mix the soil layers to depths of at least 1.5 to 2 m. Water flowing down this unstratified soil will result in downward growth of the roots toward the water table.

Mortality

Survival was very high for willows and cottonwoods (Table 9). Only six of eighty-seven of these species died prior to the winter dormancy period. (Several were killed by vagrant cattle but these were not included in mortality rates.) Honey mesquite seedlings from cow dung showed slight but not significantly ($p \geq 0.05$) greater survival than seedlings germinated in the greenhouse.

Table 8. Growth rates for four species of trees on the revegetation site during 1977.

	Growth (cm)/100 days	
Species	Height	Crown Diameter (cm)
Palo verde, Site III, unwatered	13.7	21.6
Site I, unwatered	3.3	11.4
Site III, watered, begin May	64.0	68.8
Site I, watered, begin June	44.7	87.1
Cottonwood		
Sand	27.4	47.8
Loam	25.7	58.9
Willow	1.6	41.7
Honey Mesquite		
From seed	69.1	36.3
Planted	39.6	29.7

Table 9. Mortality for three tree species planted on the revegetation site during 1977.

Species	Total Planted	Total Surviving
Willow	21	17 (81.0%)
Honey Mesquite		
Transplants	53	30 (56.6%)
From seed	35	24 (68.9%)
Cottonwood	66	62 (93.9%)
Totals	175	133 (76.0%)

Atriplex species

Quail bush and salt bush were planted by broadcast seeding in March. This proved to be almost totally unsuccessful. In May about 250 quail bush were transplanted and by August all were dead. In October both species of Atriplex were planted from seed (about 200) in rows about 18 m long.

A. lentiformis was planted in loam on three watered subdivisions on the site. By March a significant ($p<0.01$) number of those plants present in November had died on sites I and III. Although germination was less successful or retarded on site II, survival to March was good (Tables 10 and 11).

A. canescens was planted in loam on three sites in sandy areas with loam transported in to promote germination. The seeds germinated in March, which was contrary to the observation for A. lentiformis which showed a decline in numbers from November to March. Seeds of both species were sown in approximately the same way but they were not counted, thus comparison of germination between sites was not possible.

A. lentiformis was significantly ($p<0.01$) taller on site II than on either of the other sites and A. canescens on site I grew significantly ($p<0.01$) taller than either species on all sites (Table 9). In general A. canescens grew faster, even though it may have germinated later than A. lentiformis.

These plants were all destroyed before it could be ascertained whether or not this trend would have continued. Similarly we learned nothing about long term survival of either species of Atriplex.

Table 10. Germination rate per meter of Atriplex planted in October, 1977. The numbers in parentheses are the number of one meter strips sampled.

	A. lentiformis (loam)			A. canescens (sand)		
	Site			Site		
	I	II	III	I	II	III
Nov. 6	9.4(35)	2.8(36)	9.9(20)	0.4(40)	0.3(41)	1.2(37)
Mar. 6	5.6(31)	4.0(64)	6.8(11)	2.9(41)	1.0(55)	3.9(52)

Table 11. Growth rates (cm) of Atriplex lentiformis and A. canescens from October to March

	Atriplex lentiformis			Atriplex canescens		
	Loam			Sand		
	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Site I	174	2.00	1.45	117	3.71	4.06
Site II	225	2.97	3.43	55	2.54	2.29
Site III	75	2.08	1.32	200	2.59	2.44

Insect Populations

Since many species of birds inhabiting an area are insectivores it is critical for successful enhancement to increase insect populations. We monitored insect populations by systematically sweeping watered and unwatered portions of the revegetation site in November and December. Within either month total insects captured, the biomass, and number of families represented was much greater in vegetation on watered areas (Table 12). In the same period insect biomass decreased in unwatered areas. It should be emphasized that watering was continued in fall and winter even though most of the vegetation was dead or dormant. Dense patches of annuals, primarily thistle (Salsola kali) and smother weed (Bassia hyssopifolia) which were absent on the unwatered portions, harbored the insects on the watered portion.

Rodents

We trapped rodents in the revegetation site in April 1977, prior to any tree planting. In 270 trap nights only one rodent, a Merriam kangaroo rat (Dipodomys merriami) was caught. The area was trapped again in October, following the revegetation effort, and five desert pocket mice (Perognathus penicillatus), two Merriam kangaroo rats, and two cotton rats (Sigmodon hispidus) were trapped. Concurrently no rodents were caught in 270 trap nights on unwatered and unvegetated portions. Although preliminary, these data indicate an increase in rodent numbers on watered portions of the revegetation site.

Rabbits

We acquired some information relative to rabbit (Sylvilagus auduboni) response to watering. From April through December 1977 we counted all rabbits seen between the river and the riparian vegetation (consisting mainly of salt cedar, screwbean mesquite (Prosopis pubescens) and arrowweed (Tessaria sericea) along a 3.2 km stretch just north of the watered area. A similar count was made along the 1 km portion adjacent to the watered area. These data, when adjusted to represent equal areas, indicated that rabbits were equally abundant at the revegetation site as along riparian vegetation (Table 13), at at least through September. After that rabbits may have become less abundant on the revegetated site.

Table 12. Insect data from watered and unwatered portions of the dredge spoil.

Month	Number of Sweeps with insect net	Catch: Total Number	Catch: Total Biomass(g)	Number of Families Represented
November				
Unwatered Area	2000	139	0.2171	10
Watered Area	2000	365	0.8114	30
December				
Unwatered Area	2000	83	0.1690	13
Watered Area	2000	601	0.9476	31

Table 13. Relative abundance of rabbits per km of road adjacent to riparian vegetation and adjacent to the watered area. Number of censuses is in parentheses.

Month	Number Adjacent: Riparian Vegetation		Watered Area	
April	(1)	2.3	(0)	-
May	(10)	1.9	(1)	7.0
June	(9)	1.6	(7)	1.6
July	(23)	1.5	(23)	1.3
August	(20)	0.8	(20)	0.8
September	(12)	0.4	(12)	0.5
October	(22)	0.5	(22)	0.2
November	(7)	0.2	(7)	0.0
December	(7)	0.2	(7)	0.0
Mean June-December		0.8		0.6

The Avifauna

Monthly population changes

Total bird numbers increased from 14 per 40 ha in April 1977 to 1,076 in January 1978 (fig. 5). Increases were most dramatic among seed-eating species. This is almost certainly related to seed production by the annuals that developed on the site. Higher order consumers (insectivores, Roadrunners, hawks, etc.) also showed substantial increases by January 1978, indicating that moist conditions and dense vegetation led to the establishment of significant numbers of insects and rodents (see appropriate sections above).

Comparisons with native vegetation

Total bird densities per 40 ha in October through December (fig. 5) were much greater on the revegetation plot than in any native vegetation used as controls (native vegetation which had burned or had low sparse vegetation), but number of species tended to average higher in controls (fig. 6). In December the revegetation site surpassed screwbean mesquite and salt cedar in numbers of birds per 40 ha. In December the revegetation site had more species than screwbean mesquite and by February had surpassed all control areas. Most of the birds present used the dense patches of annuals extensively.

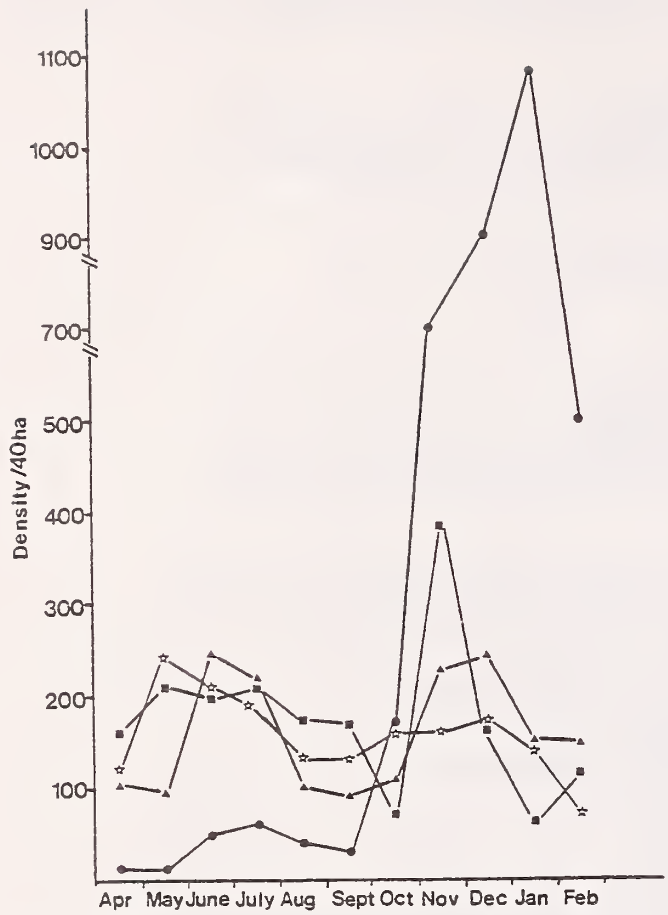

Figure 5.--Monthly bird densities per 40 ha on a revegetation plot during 1977.

Rapid recovery from losses resulting from clearing

The management implications of these data indicate that a quick recovery from loss of habitat can be accomplished easily for winter birds by establishing dense patches of annuals. Our major concern in clearing salt cedar or any other vegetation and replacing it with something that should be better for wildlife lies in the fact that initial loss of wildlife following clearing might never be compensated. This should not be difficult to understand nor should any party involved with revegetation efforts fail to understand it. Additionally, no matter how good plans look on paper, there is always a chance that the potential will never be realized for a myriad of reasons. For example, when trees are involved, their slow rate of growth means that whatever potential they might have when mature or nearly mature will not be realized for one or possible two decades. Death of any portion of these trees during early years will mean a reduction in the long term estimated value of the final habitat.

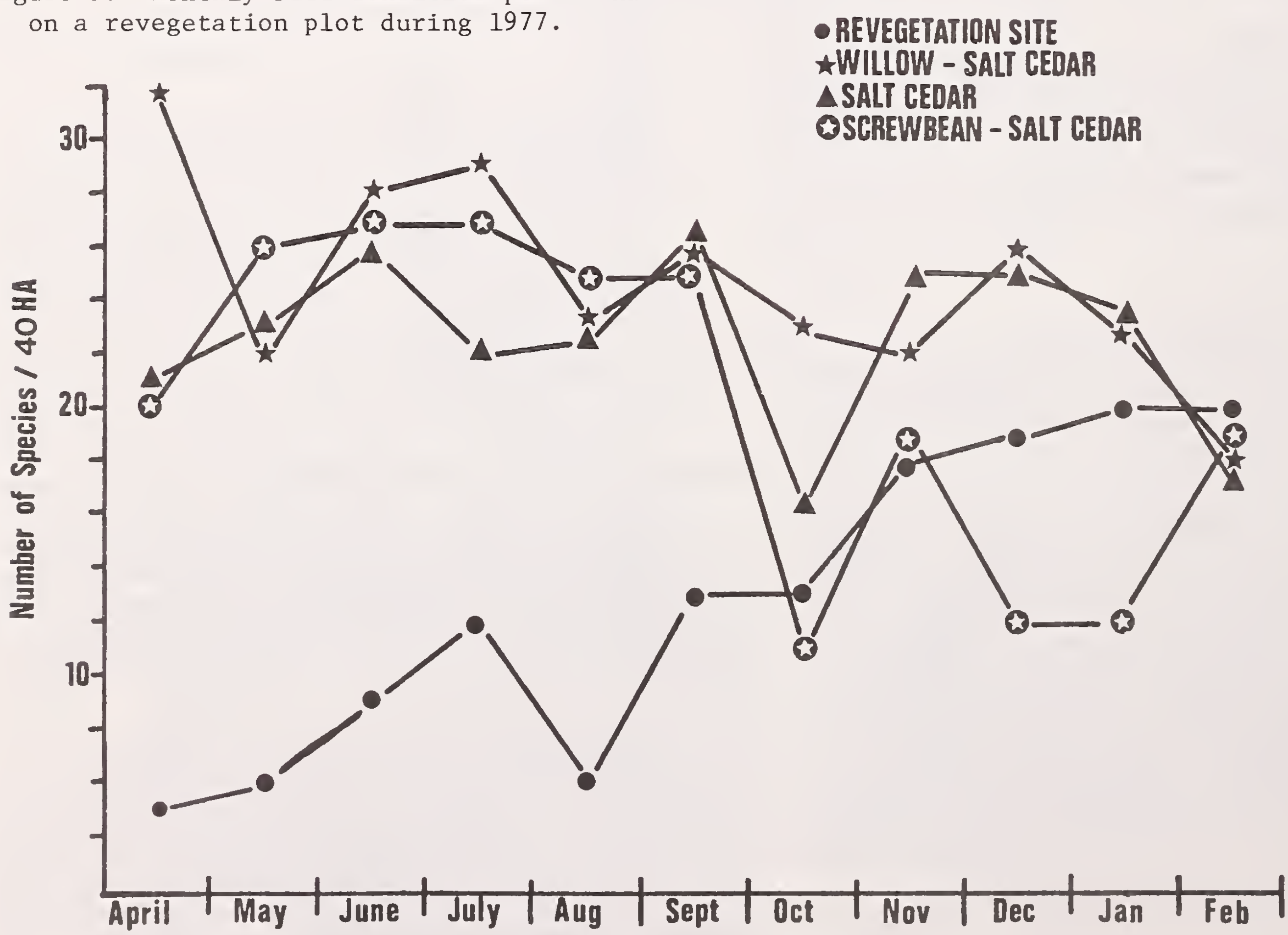

Figure 6. Monthly number of species per 40 ha on a revegetation plot during 1977.

Superimposing communities on the same area

Our first year's results showed that superimposing three vegetative types should be an integral part of revegetation efforts. Theoretically, a slow growing community would be superimposed upon two rapidly growing ones. Our objectives now are to encourage growth of as many annuals as possible while watering is occurring, presumably over a three-year period. Rapidly growing annuals will form an early ephemeral community of high value to birds, at least in winter. At the end of a three-year period watering will be terminated. The ephemeral stage, dominated by annuals, will be replaced by a community of shrubby perennials (quail bush, ink weed, and others) which will gradually give way to a community dominated by trees. The extent to which shrubs will persist in the understory will depend on the density of the tree overstory.

In summary, superimposing three communities on a single area permits development of an early ephemeral stage dominated by annuals, which preliminary data indicates will have high wildlife value, at least in winter. The principal advantage of this ephemeral stage is that it develops rapidly and easily and will therefore help to quickly offset initial losses resulting from clearing. The second stage (shrubs) will continue to help offset early losses and, in contrast to annuals, will be able to persist without watering. Finally, as trees mature they will approach their full potential value to wildlife. A new balance of shrubs and trees will eventually be achieved.

There is another reason for doing all that can be done to encourage the first two stages. If a tree dies and it cannot be replaced, there will be a reasonably good chance that the shrubby species will persist. Consequently the area originally designed to support a tree will retain some value to wildlife.

Any long range vegetation management plan will be more successful if one realizes that 25 to 50 percent of the cottonwoods, willows, and other trees may die before reaching maturity. Death due to wind damage, disease and other factors will take a toll. Every time a tree dies prior to the period for which wildlife enhancement estimates have been calculated the more inaccurate the estimate will be. It is highly improbable that long term enhancement estimates will ever be fully realized. With this in mind the importance of an ephemeral community is obvious. It should also be evident that rapid establishment of a relatively permanent shrubby community is critical. If all three communities are successful there will probably be a sizeable enhancement value to wildlife over the years, possibly even greater than the predicted. If the final stage falls short of expectations, the success of earlier stages may still result in long term enhancement of an area. If either of the first two stages are unsuccessful, in all probability the long term value to wildlife will be less than the value of the vegetation cleared. Enhancement values have to be calculated in terms of total productivity over the same time period.

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Regulating Critical Riparian Lands: A Challenge in Intergovernmental Cooperation[1]

Jon A. Kusler[2]

Abstract.--Many federal, state and local programs now regulate, protect, and manage riparian lands. However, these efforts are handicapped by limited geographical scope, narrow objectives, insufficient data, and poor coordination. A new National Riparian Habitat program could help overcome these problems. It would build upon and fill in the gaps in existing programs with the aim of strengthening programs at all levels of government for regulating and otherwise managing particularly sensitive riparian lands. Such a program should have a riverine focus and involve data gathering, research, technical assistance, and coordination.

One objective of this symposium is, as I understand it, to help stimulate governmental efforts to improve the management and protection of riparian habitat through research, planning, technical assistance, regulation, acquisition and perhaps other approaches. I applaud such an objective. But, do we need a National Riparian Habitat Protection Program? If so what form should it take? What lessons have been learned from national state and local programs dealing with the coastal zone, flood plains, scenic and wild rivers and wetlands which might be applied in such an effort?

Do We Need a National Riparian Habitat Protection Program?

As broadly understood by the scientific and legal community, riparian lands encompass a wide range of coastal, great lake, riverine, and lacustrine environments which share one major characteristic--proximity to water. In the last decade Congress, the states and localities have adopted a wide range of regulatory and management programs for these areas. These efforts are targeted at discrete riparian. lands. The National Coastal Zone Management Program, 32 state coastal zone programs and thousands of local programs address coastal and estuarine riparian environments, usually with an emphasis on coastal wetlands and recreation areas such as beaches and barrier islands. The federal 404 regulatory program, state wetland regulatory efforts in at least 20 states, and at least 1000 local government regulatory efforts apply more specifically to coastal, riverine, and inland wetlands. The National Flood Insurance Program, state flood plain regulatory programs in at least 24 states, and local flood plain regulatory programs adopted or planned for at least 16,000 communities apply to the 100-year flood plain and flood way or coastal high hazard areas in coastal, riverine, and, in some instances, lacustrine flood hazard areas. The National Scenic, Wild, and Recreation River system applies to at least 19 rivers; state scenic, wild or recreational river programs have been adopted in at least 24 states. At least six states and several thousand localities have adopted so called shoreland regulatory programs for lake and streamshore areas.

Other federal, state and local efforts apply to riparian wildlife habitat, habitat for rare and endangered species, scientific areas, "critical areas", dredge and fill activities, comprehensive land and water uses throughout communities, point and nonpoint source of water pollution, and extraction and use of surface and ground waters. These programs collectively provide some protection for riparian habitat but are subject to several serious limitations:

[1]Paper presented at the National Riparian Ecosystem Symposium, Callaway Gardens, Georgia, December 11-13, 1978.

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First, the programs are limited in geographical scope. Most of the state and local efforts are concentrated in the coastal states, New England and the upper Midwest with little representation from the South, West or lower Midwest. Federal efforts such as the 404 permit requirements have not been vigorously enforced in these areas. In addition, emphasis at all levels have been upon the protection and management of coastal and lake shorelines with little attention to riverine systems.

Second, existing efforts have limited objectives. For example, flood plain regulatory programs--the most extensive efforts--are directed to minimization of flood hazards, not to the protection of wildlife. In fact, regulations often encourage filling in the outer flood fringe areas.

Third, efforts lack sufficient data. Several years ago I conducted a nationwide survey of major data deficiencies in federal, state, and local critical area programs. This survey revealed that wildlife, vegetation and hydrologic data were major deficiencies in all efforts. No federal agency was systematically collecting habitat data and supplied this data to other agencies, states and localities. In addition many of the potential federal data sources such as orthophotos which might be used for this purpose were at too small a scale or too low a resolution.

Fourth, existing efforts are poorly coordinated. Most are organized on political boundaries, not according to ecological or hydrological systems.

Do we need a new federal effort to address these deficiencies or could we beef up individual existing programs? I believe that a new federal riparian effort is needed to clearly focus attention at all levels of government upon riparian habitat. But it should fill in the gaps in existing programs rather than create a new, competitive and repetitive bureaucracy. Its form and content should reflect lessons learned from the National Coastal Zone Program, the Flood Insurance Program, the Scenic and Wild River Program, Federal 404 efforts and other efforts. It should be implementation-oriented with a focus upon regulation and acquisition. It should address, on a priority basis, particularly sensitive riparian lands. Above all, it should improve and strengthen other federal, state, and local regulatory and management programs affecting riparian habitat. This, of course, is a major challenge since autonomous efforts are the rule.

What Should Be the Form and Content of a New Program?

What might be included in such a program in light of lessons learned with similar programs?

First, the effort should focus upon coordination, data gathering, research, technical assistance and perhaps grant-in-aid focus. It should not, at least initially, play a direct management role. Experience with the Coastal Zone Program, the National Flood Insurance Program and the 404 program strongly supports a technical assistance focus.

By inventory, I mean mapping and other data gathering at relatively large scale for priority habitat in threatened areas such as urban fringes and recreation areas. This could be accomplished as part of the proposed broader National Habitat Inventory.

By research, I mean not only traditional wildlife research but management-oriented research such as the investigation of the interrelationships between flooding and habitat, the impacts of various types of development on habitat values, and techniques for minimizing impact.

By technical assistance, I mean: the conduct of workshops in habitat evaluation and protection for legislators, agency staff, and others; habitat maps and inventories; the supply of data sources such as air photos to other agencies, states and localities which can be interpreted in greater detail; one-on-one training of managers in habitat analysis; and assistance to agencies at all levels of government in evaluating individual proposed projects.

By grants-in-aid, I mean inventory, planning, and program development grants to states and localities resembling perhaps those of the Coastal Zone Management Program.

Second, it should, in my opinion, be at lease initially targeted at riverine flood plain areas since these areas are as yet poorly protected in many areas of the country and under increasing development pressure. Much of the riparian habitat is now being addressed by federal, state and local programs. A national riverine riparian habitat program would be appropriate in light of several factors:

(1) Improvements in the water quality in many of the Nation's rivers to their natural or near natural condition by 1983 (E.P.A.'s water quality goal) provides new wildlife and recreational opportunities. However, clean waters also attract commercial, residential,

and industrial development to adjacent riparian habitat areas.

(2) Rivers are looked to increasingly as a source of urban water supply and waste disposal as populations increase and pollution problems are abated. This creates new threats to riparian habitat.

(3) Riverine flood plains are often the last remaining urban open spaces. Recent case studies in 17 cities by the National Park Service and Bureau of Outdoor Recreation revealed that flood plains were prime sites for new outdoor recreation.

(4) Rising costs of agricultural land is encouraging channelization, drainage and intensive agricultural for many of the remaining riverine flood plain areas in a natural condition.

(5) Riverine flood plains are areas with major redevelopment potential. Often the oldest areas of cities are subject to blighted conditions and repeated flooding, redevelopment is now underway or considered for many such areas. Riparian habitat needs should be considered in rehabilitation efforts.

A riparian habitat initiative should also help establish habitat inventory specifications and initiate data gathering and technical assistance programs for other federal, state and local programs addressing coastal and lake riparian areas, but the primary emphasis of the new program would be riverine.

Third, it should be targeted at the land and water regulators and public land managers. Unfortunately much of the federal mapping and data gathering carried out over the last two decades has been of limited value to management efforts due to their small scale and the failure to gether specific types of data needed for management. For example, early flood plain maps developed by the USGS and the Federal Insurance Administration have proven of limited value in state and local regulatory efforts due to small scale and inaccuracies. Identification of the sites of severe flooding and habitat for rare and endangered species are more useful to a federal, state or local regulatory agency which must say yes or no to development applications than generalized data concerning wildlife or vegetation type.

To better serve the needs of managers, any new national effort should be built upon manager need surveys and should involve managers in the design and implementation of research, data gathering, and technical assistance programs.

Fourth, the efforts should be designed to involve and strengthen state and local roles in riparian habitat protection. Experience with the Coastal Zone Management Program, the 404 program and the National Flood Insurance program suggests that a hierarchy of efforts is essential to help formulate and implement policies for particular areas. Such a hierarchy may best involve federal data gathering, technical assistance, grants-in-aid and standard-setting with more detailed state standard-setting and regulation. Local governments should play significant although not exclusive role in the administration and enforcement of efforts.

Local as well as state involvement is needed for several reasons despite a general feeling in Washington that local governments are ineffective in regulating land and water uses due to real estate pressures, inadequate expertise, and limited geographical perspective. Experience with cooperative federal and state flood plain, wetland, and coastal area regulatory programs reveals that it is difficult to enforce higher level efforts without local cooperation and the continuous monitoring that interested local governments and interest groups provide. In addition, local governments and interested landowners may have essential time-series habitat data such as the location of a particular species (e.g., a bald eagle's nest) which cannot be gained by a quick survey or air photo interpretation.

Could or should a national riparian habitat program be organized or implemented on a regional basis? Perhaps? Particularly if it is primarily a data gathering and technical assistance effort. But what regions? Ecosystem regions? Topographic regions? Political regions? River basin regions? I can't answer this question. However, a river basin approach might be appropriate due to the presence of ongoing river basin planning and inventory efforts and the close relationship between habitat and hydrologic regimes.

Fifth, the effort should focus upon priority areas where there is both a high probability of prime habitat values and development threats such as areas suggested for new water resources projects, new agricultural activities or mining. In my estimation, relatively detailed studies should be conducted for these areas before there is any attempt to survey riparian habitat as a whole.

Sixth, a habitat program should, in my opinion, take a broader carrying capacity focus to facilitate the efforts of land management and regulatory agencies to actively protect essential habitat features while permitting some use of riparian lands. Such uses are

inevitable for many areas and the test of any national riparian program will be in its ability to protect the most sensitive lands while minimizing the impact of riparian uses. For example, a riparian program might simultaneously classify riparian lands both according to habitat potential and other types of use potential. Riparian lands might be classified for:

(1) wildlife purposes,

(2) flood storage and flood conveyance areas,

(3) various levels and types of outdoor recreation ranging from picnic areas to wilderness areas,

(4) various types of scientific study and use,

(5) use as tertiary treatment areas (e.g., wetlands, certain forests),

(6) various types of agricultural use,

(7) forestry operations,

(8) mineral resource extraction (e.g., sand and gravel deposits),

(9) commercial and industrial development,

(10) residence and second homes.

Recommendations should then be made concerning areas which need complete protection, partial protection and no protection through acquisition, regulation, or other techniques. This would not be easy. But who is doing this essential task?

In summary, then, I believe we do need a National Riparian Habitat program with a riverine focus, involving data gathering, research, technical assistance, and coordination. It would build upon and fill in the gaps in existing efforts with the aim of strengthening programs for regulating and otherwise managing particularly sensitive riparian lands. Specifically it would involve:

(1) Habitat inventory and mapping at relatively large scale (e.g., 1/24,000) and high resolution on a priority area basis which would address topics of particular interest to managers such as site of rare and endangered species and areas of natural diversity. This data would be periodically upgraded. Emphasis would be not only upon data gathering but dissemination of data to users.

(2) Technical assistance to other federal agencies, states, local governments and perhaps to private groups such as the Nature Conservancy. Such assistance would include training workshops in the identification of habitat types, supply of air photos on a periodic basis to constituency groups and agencies with training in the technique for their interpretation; the preparation of manuals and other materials dealing with techniques for assessing and minimizing the impact of development upon riparian habitat; and assistance in evaluating particular areas and development proposals for those areas;

(3) Research concerning the most appropriate scales and types of data gathering to serve management needs; the interrelationships of riparian lands and nearby water bodies (this is a high priority from a legal perspective); the compatibility of particular riparian uses with maintenance of habitat; techniques to assess the impact of development upon habitat; and techniques to minimize the impact of development upon habitat; and

(4) Efforts to upgrade existing flood plain, wetland, coastal area, shoreland and other efforts to more effectively evaluate and protect habitat.

Habitat protection is an important topic with a large constituency. A new program should meet the needs of this constituency with imagination and common sense.

Position Paper:

Environmental Protection Agency Programs Relating to Riparian Ecosystems[1]

David G. Davis[2]

The principal responsibility of my group is the implementation of Section 404 of the Clean Water Act--that is, the national program for the control of dredged and fill materials discharge.

It's my pleasure to be here this morning and to be able to address this audience on EPA's policies toward the management and protection of wetland and riparian habitats. While we are neither uniquely concerned with wetlands nor with riparian systems, both of these are major elements in the scope of Section 404 coverage.

Briefly, I intend to discuss:

(1) The rationale for EPA's interest in wetlands habitats.

(2) The directives which form the basis for EPA's wetlands policy and

(3) The development of State wetlands management programs.

In considering the rationale for EPA's interest in wetland habitats, it must be noted that EPA's environmental concerns encompass water uses, criteria regarding pollutants and water related resources. Because ecosystems in wetlands and floodplains are dependent on water (i.e. water related resources) EPA's interests also extend to these areas.

It has been established that the filling or other destruction of wetlands diminishes the production of food on which organisms depend. These actions also reduce the capacity of the aquatic ecosystem to assimilate pollutants, and inhibit the maintenance of an oxygen balance within the aquatic ecosystem. Moreover, dredging and filling operations often increase the rate of stream flow, thereby foreshortening the period of natural cleansing and exacerbating downstream flooding, which in turn can serve to wash additional pollutants into waters. Since we know that wetlands and floodplains serve such valuable functions-and probably others we don't yet understand--we are vitally interested in protecting these areas.

In considering the directives which form the basis for EPA's wetlands policy, one should note that Congress, by means of the Federal Water Pollution Control Act amendments of 1972, provided EPA with strong and comprehensive policy directives for the control of water pollution. Under the current law, the US EPA is the national arbiter of the environmental effects resulting from the discharge of dredged or fill material into the waters of the United States. Of primary concern to EPA in this regard is that hydrological modification, such as that which occurs from dredging and filling operations, results in the alteration of the natural capacity of a water body to cleanse itself of pollution and to support a healthy biological system.

Within the framework of the FWPCA, two provisions address the control of hydrologic modification; section 208 (Planning, and Best Management Practices) and section 404 (Dredge and Fill). Because section 208-planning is intended to guide the administration of all the permit programs under the Act, it arguably is the pivot around which the entire statutory scheme eventually will revolve. In contrast to section 208, section 404 of

[1]Paper presented at the National Symposium on Strategies for the Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

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the statute has been an immediately available, specific mechanism for the control of hydrologic modification since its enactment as part of the Amendments of 1972.

Although the 1972 Amendments assigned to the Corps of Engineers the responsibility for administering the section 404 permit program, EPA was given the environmental role. Section 404 authorizes the Corps of Engineers, in conjunction with EPA, to regulate (on a case-by-case basis, through a permit program) discharges of dredged and fill materials which are a prinicipal source of hydrologic modification.

The 1972 law (FWPCA) added to the limited "dredge and fill" permit requirements of the 1899 Rivers and Harbors Act in several ways:

(a) It directed the Corps to consider water quality in granting or denying permits for discharges of dredge or fill material.

(b) It required permits for discharges into "Waters of the United States" rather than just "Navigable Waters.". In effect, this extended the areas within which permits are required. In the case of saltwater wetlands the practical result has been to extend a permit requirement to all parts of the wetlands, "upper" as well as "lower". For inland wetlands, however, the result was to extend jurisdiction to all waters to which the Commerce Clause of the Constitution applies.

(c) It gave the EPA an important role in the revision and administration of the permit program.

The 1977 Amendments -- known as the Clean Water Act -- further defined the national program for dredged and fill material control by:

(a) providing a mechanism for the assumption of permitting responsibilities by qualified states,

(b) establishing a number of exemptions or exclusions for certain categories of agricultural and industrial activities,

(c) providing for an alternative control program under Section 208 for certain categories, operating through State-controlled best managment practices, and

(d) providing an exemption from 404 permitting for those major projects specifically authorized by Congress and for which an EIS is submitted which includes consideration of the 404(b) Guidelines.

Other federal directives which serve differing purposes relating to the physical management of coastal floodplains are:

- Coastal Zone Management Act of 1972
- National Flood Insurance Act of 1968
- Flood Disater Protection Act of 1973
- Flood Control Acts
- Fish and Wildlife Coordination Act
- National Environmental Policy Act
- Executive Order 11988, Floodplain Management
- Executive Order 11990, Protection of Wetlands

These laws and directives serve purposes relating to the physical Management of coastal floodplains. Appendix I briefly identifies the goals of these directives and those of the Clean Water Act.

Historically, most localities have made little effort to control dredging, filling, and the building of offshore structures, any of which can alter basin floors. Increasingly, however, localities are becoming aware of the impact that these activities have on water circulation, erosion, and water pollution. Accordingly, some localities are trying to influence federal and state judgements affecting these activities.

As stated above, the 1977 Amendments permit States to substitute their own program of controls on discharges of dredged or fill materials for portions of the program implemented by the Corps of Engineers. EPA guidelines referred to as

the 404(b)(1) guidelines, that set the basic framework for the Corps, also set the framework for the state program. After a state requests approval of its program, EPA is allowed 120 days to review and approve or disapprove the request. To date, no State has made formal application, but a number of States have indicated varying degrees of interest.

States are allowed to assume the "404" responsibilities only for non-navigable waters and adjacent wetlands. (the so-called Phase II and III waters). Normally this would exclude saltwater wetlands, and some areas of freshwater wetlands which remain subject to overlapping state and federal permit programs in many states.

In areas where the Corps implements the Section 404 requirements, the EPA advises the District Engineer on permit applications. EPA gives special attention to that program which allows a "general permit" for certain classes of activities. A general permit can be issued if each action causes only minimal adverse impact on water quality, and if as a class in a particular location, the actions have minimal cumulative effect. Once issued, a general permit eliminates the requirement for a separate permit for each individual action. It may be valid for as long as ten years.

Dredging and filling and other uses that can alter wetlands are in fact regulated by many states. State controls are an important link in the program of state, federal, and local interest in wetlands management. Communities should determine what type of program is run in their state, and be alert for possible future changes such as the following:

(1) The coordination of federal and state permitting procedures in saltwater wetlands. Successful tests in Florida and the San Francisco Bay Region are expected to point the way to integrated application and hearing procedures.

(2) The substitution of state for federal Section 404 authority in freshwater wetlands not adjacent to navigable waters.

(3) The implementation of "Section 208" Regional Water Quality Plans for the federal Clean Water Act. These plans can include "best management practices" (guidelines and standards for pipelines and light structures likely to be located in saltwater wetlands, for example). The best management practices may also be used to set standards in section 404 permit proceedings.

(4) The coordination of state dredge-and-fill regulations with state coastal-zone management, which may give opportunities for building awareness of the policy objectives served by the CZM program.

In summary, the problem of "saving" wetlands and other riparian habitats is to prevent marshes, swamps, open shallow waters and seasonally flooded lands from being drained, permanently flooded, or filled, hence, losing their value as aquatic ecosystems and wildlife habitats. It is EPA's intent to accomplish this objective by employing the mechanisms which I have just described, and by ensuring coordinated advanced planning for all projects involving dredge and fill operations among all interested agencies and parties by means of the "404" Guidelines.

Appendix 1

Stated Goals of Federal Authorities Bearing on Physical Management of the Coastal Floodplain

<u>Clean Water Act</u>

-- Restore and maintain chemical, physical, and biological integrity of the nation's waters. (Sec. 101(a))

-- Eliminate discharge of pollutants into navigable waters by 1985. (Sec. 101(a)(1))

-- Protect and propagate fish, shellfish, and wildlife and provide recreation in and on the water (wherever attainable) by July 1, 1983. (Sec. 101(a)(2))

-- Adequately control sources of pollutants in each state through areawide waste treatment management planning. (Sec. 101(a)(5))

-- Prohibit discharge of toxic pollutants in toxic amounts. (Sec. 101(a)(3))

National Flood Insurance Act of 1968 and Federal Disaster Protection Act of 1973

-- Ensure availability of flood insurance for residents of flood-prone areas through the means of a federal subsidy.

-- Achieve local land use and control measures designed to guide the rational use of the floodplain as a condition for the availability of federally subsidized flood insurance.

-- Substitute insurance to eventually replace federal disaster relief for flood occurrences, so that property owners will contribute to their own protection and be more fully indemnified (without having to repay a federal disaster loan) when flood loss occurs.

Coastal Zone Management Act of 1972

-- Preserve, protect, develop, and where possible restore or enhance, the resources of the nation's coastal zone, including those coastal waters and the adjacent shorelands that are strongly influenced by each other, for this and succeeding generations. (Sec. 303(2))

-- Encourage and assist the states to exercise effectively their responsibilities in the coastal zone through the development and implementation of management programs to achieve wise use of the land and water resources of the coastal zone, giving full consideration to ecological, cultural, historic, and aesthetic values as well as needs for economic development. (Sec. 303(b))

-- Encourage all federal agencies engaged in programs affecting the coastal zone to cooperate and participate with state and local governments and regional agencies in this effort. (Sec. 303(c))

-- Encourage the participation of the public, of federal, state, and local governments and of the regional agencies in the development of coastal zone management programs. (Sec. 303(d))

Fish and Wildlife Coordination Act

-- Provide that wildlife conservation receives equal consideration and is coordinated with other features of water-resource development programs through the effectual and harmonious planning development, maintenance, and coordination of wildlife conservation and rehabilitation. (Sec. 661)

Flood Control Act

-- Preserve and protect established and potential uses of the Nation's rivers; provides aid to the consideration of projects on a basis of comprehensive and coordinated development; and limit the authorization and construction of navigation works unless they substantively benefit navigation and can be operated consistently with appropriate and economic use of the rivers by others.

Executive Order 11990, Protection of Wetlands

-- Avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands and avoid direct or indirect support of new construction in wetlands whenever there is a practicable alternative (in federal programs).

-- Reinforces Section 404 of the federal Clean Water Act with specific policies for federal construction projects.

Wetlands Policy: U.S. Environmental Protection Agency

-- Preserve the wetland ecosystems and protect them from destruction through waste water or nonpoint source discharges by treatment or control, or the development and construction of waste water treatment facilities, or by other physical, chemical or biological means.

Preservation of the Nation's Wetlands: Department of Transporation

-- Assure portection and preservation of wetlands to the fullest extent practicable during

planning, construction, and operation of federal transportation facilities, and federally assisted state and local transportation projects.

<u>Executive Order 11988, "Floodplain Management"</u>

-- Requires federal agencies to revise their procedures for considering the impact that their actions may have on potential hazards from flooding.

-- Where a practicable alternative exist, agencies should avoid activity in the floodplain.

-- Avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and avoid direct or indirect support of floodplain development whenever there is a practicable alternative (for federal activities).

Position Paper:

A Riparian Policy for Changing Times[1]

John R. McGuire[2]

Abstract.--The Forest Service recognizes the importance and unique values of riparian ecosystems, and the increasing public awareness of these values. Policy directions, to be issued shortly, state that these lands on the National Forest System will be managed for their unique values, following the principles of multiple use and sustained yield, and meeting stewardship responsibilities for protecting soil, water, and vegetative resources.

"The times change and we change with them." This was said more than a thousand years ago by a Roman emperor. And yet I can think of no better motto for managing natural resources, especially the public lands. The resources themselves are constantly changing, evolving. But, more importantly, our use of those resources changes, and with this, the value of a particular resource, in human terms, grows or diminishes. Part of this shifting of values may be simply recognizing the true worth of a resource, or the fact that it is becoming scarcer. In the past, that "worth" often revolved around changing commodity needs. Today, I'm glad to be able to say that the "worth" of a resource depends as well on its intrinsic value in the natural cycle, its unique or fragile qualities, and the recognition--finally--that human beings have an obligation to pass on to future generations a land base that is both productive and diverse.

This is certainly true of the riparian ecosystems. Today, the public recognizes the value--and the fragile nature--of these lands.

Yet it was only a few years ago that scientists recognized the riparian ecosystem as one of the richest zones for fauna. And it was just a year and a half ago that the Forest Service initiated the first symposium on the "Importance, Preservation and Management of Riparian Habitat."

The Forest Service, as a public land managing agency, is responding to this growing public awareness of the riparian ecosystems' value, and making sure that these values are given appropriate play in our management of the National Forests and Grasslands. Likewise, we recognize that people still want the commodity values that riparian ecosystems offer so abundantly.

Resource policy and management must be dynamic--this is fundamental. Since the beginning, Forest Service management has evolved to meet changing needs, concerns, and values, and new scientific knowledge. It has become very evident in recent times that there is considerable concern for the riparian ecosystems. Therefore, our decision was easy--we had to update our riparian policy and management, if needed; stay in tune with public sentiment on managing these lands; and make sure we were moving in the best direction.

Last July, I established a Task Force to examine current streamside-riparian area management on the National Forests and Grasslands. The mission was explicit--determine if the existing national policy needs changing, and if management strategies are adequate to ensure that riparian values are recognized and balanced in National Forest System management.

Now the results are in--and we found that our basic policy on riparian management is sound. But we want to go beyond merely a reaffirmation of policy. We want to ensure that the letter, intent, and philosophy of this policy are evident wherever a riparian ecosystem exists on the National Forest System. The four main principles of the policy are:

1. We will plan for and manage riparian ecosystems with full recognition of their importance and unique values.

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[1]Paper presented at the National Riparian Ecosystems Symposium, Atlanta, Georgia, December 13, 1978.

[2]Chief, Forest Service, U.S. Department of Agriculture, Washington, D.C.

2. At the same time, we will manage riparian ecosystems as an integral component of the adjacent lands, under the principles of multiple use and sustained yield.

3. We will protect, and, where applicable, improve the riparian ecosystems--that is, the soil, water, and vegetation--as one of our basic stewardship responsibilities. This will be done prior to, or in conjunction with, other resource allocation decisions.

4. We will also, as policy, continue research programs on the management, ecology, and protection of riparian environments for water, fish, wildlife, timber, livestock, and recreation values and uses.

But, policy is one thing. Interpretation, and action on the ground, can be another. You know this, and I know it. So, let me explain how this policy will be--and I emphasize <u>will be</u>--integrated into National Forest land management planning. I'll start with the policy directions that will be issued shortly:

---Riparian management will encompass the requirements of Executive Order 11990 for wetlands and Executive Order 11988 for floodplains, particularly the requirements to avoid, to the extent possible, adverse impacts from activities on the riparian ecosystem.

---Public participation in all our planning and management--including that for riparian ecosystems--is assured through the National Forest Management Act.

---Land management plans will specifically state objectives for riparian ecosystems.

---We expect to classify riparian ecosystems in the Forest Service National Land Classification System that we use in land management planning. Riparian ecosystems and associated lands will be inventoried and delineated as "Capability Areas" on the National Forest System.

---Interdisciplinary teams will identify alternatives for protecting and managing riparian ecosystems as planning is done on each Forest or Grassland.

---Our land managers will use environmental assessments to evaluate both the individual and cumulative effects of proposed actions in riparian ecosystems. This will ensure that the natural and beneficial values of these ecosystems are protected as the President has directed.

---The actual on-the-ground effects of our actions within and adjacent to riparian ecosystems will be monitored and evaluated, keeping in mind the considerable expense associated with monitoring.

---Riparian ecosystems planning and management on the National Forest System will be coordinated with other Federal agencies, the States, and local governments.

In many cases, various aspects of this policy direction have been on-the-ground reality. But, I'll be very frank and say that the success of our riparian ecosystem management varies from forest to forest. This results from the diversity of ecosystems throughout the National Forest System, as well as the intense competition for the resources these ecosystems have to offer. Our national policy provides the flexibility necessary for considering each local situation.

We have the manpower, experience, and expertise already within the Forest Service to make sure that this policy is extended throughout the National Forest System.

We also recognize that research is the key to solving many of the present conflicts. When the Task Force was set up, we began to look at research needs as well. Our goal is ambitious--we want to have, by 1985, information needed for evaluating the suitability and capability of riparian ecosystems and analyzing resource trade-offs in the West.

I spoke earlier of changing times. And, we are indeed living in an era of tremendously rapid change. A number of events--changes, if you will--have occurred in the last few years to create the most favorable climate ever in which to live up to the letter of the riparian policy I've described. Under the Resources Planning Act of 1974, and the National Forest Management Act of 1976, the Forest Service has the means of tying resource goals to land capability and protection, and public needs. Just as importantly, the land management planning process which we are now refining through regulations is built on what I consider the two best foundation stones for land management in the public interest. They are: interdisciplinary planning and intensive public involvement.

We want to practice sound land stewardship by protecting the soil, water, and vegetative resources. The National Forest Management Act supports the concept that this fundamental need be recognized prior to, or in conjunction with, resource allocations.

In looking at the riparian ecosystems, the Task Force found that conflicts among uses are often most pronounced on these lands, and are most evident in arid regions where riparian ecosystems are scarce. In addition, we need more information about these lands. Scientists disagree even on the basic characteristics and capabilities of riparian ecosystems. And, as perhaps the inevitable result of rapid change over a short period of time, we now find that recent legislation, regulations, and Executive Orders overlap, so that roles of various agencies do not emerge in sharp and precise focus.

The inherent conflicts were obvious--particularly in the West, where competition for available water is a way of life, for humans and resources as well.

It came as no surprise that livestock grazing has the greatest single impact on riparian areas in the Southwest and intermountain areas. We found examples of quality streamside management co-existing with livestock grazing. And yet, we heard increasing concern that livestock grazing may be depleting the riparian conditions and fish habitat.

In most areas, the adverse impacts of timber harvesting and road construction--which were evident in the past--have largely been mitigated by better management, including specific provisions in timber sales contracts. But, concerns are still voiced in the Pacific Northwest and Alaska, where high timber values compete with high anadromous fish values.

Another sign of our times is the increase in water-oriented recreation, which affects riparian ecosystems, particularly in the East.

And, dispersed recreation was cited as harrassing wildlife and degrading habitat in unique southwestern riparian ecosystems.

Other activities which were brought out as areas of concern included: public highway construction and maintenance on National Forests, placer and hydraulic mining, removal of stream-deposited gravel, and pollutants originating from mining outside the riparian ecosystem itself.

This is perhaps the grim side of the picture--the conflict side. Now, let me focus on the brighter side--the success stories in our efforts to balance a variety of uses with protection of the riparian ecosystems. The value of these successes extends far beyond the land area they initially influence--we see in them methods that can be applied in other areas to address the conflicts found by the Task Force.

In Eastern Oregon, we've set objectives for our riparian habitat and have incorporated them into rotational grazing systems, as well as considering the impacts of all resource use. This has produced very positive improvements in the ecosystem over the past four years.

In coastal Alaska, we are determining ecological principles and developing management practices necessary to maintain fish habitats, meet water quality standards, and reach timber production goals.

In the Pacific Northwest, we are trying to determine the importance of streamside vegetation for maintaining anadromous fish habitat, and are developing methods for identifying highly productive streams. We hope to establish the importance of cover density along streamsides, the contribution of terrestrial insects from streamside vegetation, and the interaction between grazing and this vegetation.

We want to find the best ways of managing resource use within riparian areas. As an example, researchers in Minnesota, Wisconsin, and Michigan are developing management guidelines for almost 100,000 acres (40,000 hectares) of wildlife impoundments to provide habitat for waterfowl, furbearers, reptiles, and amphibians, as well as enhancing landscape diversity and recreational opportunities.

I said earlier that the times change and we change with them. I think some of these examples illustrate the magnitude of that change. I've also heard that "the only constant on this earth is change." I want to emphasize that Forest Service policy and management are not fixed or static. They, too, will continue to change and evolve, responding to both the resource and public sentiment. This is the only way in which we can truly recognize the values of the riparian ecosystems, in both ecological and human terms.

Position Paper:

Protection and Management of Riparian Ecosystems: Activities and Views of the U.S. Fish and Wildlife Service[1]

Allan Hirsch[2] and Charles A. Segelquist[3]

Abstract.--Riparian ecosystems are vital to the continued well-being of many of the Nation's fish and wildlife resources. However, land use changes and water resource development activities are jeopardizing these valuable environments. Current activities of the Fish and Wildlife Service providing for the protection of riparian resources are described, and several initiatives are outlined to strengthen riparian ecosystem protection and management programs.

Riparian ecosystems support some of the most productive and diverse wildlife populations in the United States. They also play an important, if not essential, role in maintaining wildlife populations in adjacent uplands and in supplying energy and nutrients to riverine, lacustrine, and estuarine systems. These important riparian resources are being lost and degraded at an alarming rate throughout the country as a result of developmental activities. Inasmuch as riparian ecosystems play a critical role in maintaining fish and wildlife productivity and diversity, more vigorous efforts are needed to protect and manage these valuable resources.

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[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

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IMPORTANCE OF RIPARIAN ECOSYSTEMS TO FISH AND WILDLIFE

There is no single definition of riparian ecosystem endorsed by all ecologists, but there is general agreement that these systems have certain common features. Riparian ecosystems are characterized by stream or riverside plant communities with more hydric or mesic growth habits than adjacent upland communities. They range from only a few feet in width along small western streams to several miles across along major southeastern rivers. Riparian plant communities are dependent upon high water tables or overbank flooding to meet their moisture requirements. They usually depend on overbank flooding for the deposition of substrates and nutrients necessary for regeneration, establishment, and maintenance.

The linear configuration of the riparian system, its proximity to the aquatic system, and the physical and chemical interchanges between the riparian and aquatic systems provide an astonishing number and variety of habitats that are occupied by a multitude of organisms from all trophic levels. This results in complex food webs that support some of the most productive and diverse wildlife populations of any ecosystem type.

Certain species of wildlife are restricted entirely to the riparian zone for all their life requirements, but many more are dependent on the riparian system for some critical element of their life cycle such as

food, cover, or breeding habitat. Numerous other species also make extensive use of these areas even though they are not dependent upon them.

As the riparian system interfaces with the aquatic system, it has many functional attributes that strongly influence the latter system. To a large extent, the riparian system regulates the productivity of the aquatic system by supplying organic detritus to the stream. Streamside vegetation also serves to filter sediments and other pollutants prohibiting them from entering the stream. The shading effect of riparian vegetation has a strong influence on water temperature. Roots and fallen trees provide critical habitat features for numerous species of aquatic organisms.

The ecological influence of the riparian system is not limited to the immediately adjacent aquatic system. Comprehensive research on the relationship between woodland stream productivity and adjacent forested ecosystems reveals that much of the energy and hydrocarbons in aquatic food webs originates in the forest system. Nutrients and detritus derived from riparian forests are also picked up by the flooding river and transported to the coastal estuaries where they serve a major role in maintaining productivity.

Historically, riparian ecosystems have been studied much more intensively in the arid regions of the West than in the East, and we know more about western systems. Western birds have an especially strong affinity for the vertically stratified habitat provided by riparian woodlands. Over 50 percent of all species of birds along the Verde River in Arizona depend exclusively on riparian woodlands for breeding. Many ungulates in the mountainous regions of the West winter in lowland riparian areas. Beaver depend heavily on riparian woodlands for food and construction material for lodges and dams. Although data have not been adequately summarized for all vertebrates, it is widely recognized that many other western species are dependent upon the unique set of characteristics provided by the land-water interface of the riparian ecosystem.

In the Prairie States, fringes of riparian woodland along the major rivers and their smaller tributaries provide the major, and frequently the only, source of woodland cover in these predominantly grassland or agricultural regions. In the colder latitudes riparian areas are critical sources of winter cover for non-migratory species. Pheasant populations in some northern prairie regions are closely correlated with the availability of riparian cover. The extension of eastern species into the West is determined in large part by these fingers of riparian woodland extending along rivers and streams. Riparian zones also provide migratory or dispersion pathways for many species of wildlife. The north-south riparian zone of the James River in South Dakota is used as a migration corridor by over 160 species of waterfowl, shorebirds, songbirds, and raptors. The wild turkey is especially dependent on bottomland forests for communal roosts.

Riparian ecosystems are no less important to wildlife in the East. At least 300 species of migratory and resident birds utilize the Atchafalaya River floodplain at some time during the year. Large numbers of waterfowl use flooded bottoms for wintering areas, mast from floodplain timber frequently providing the bulk of their winter diet. In Louisiana over 90 percent of the white-tailed deer are found in bottomlands even though this type makes up only 50 percent of the potential deer range in the State. The largest trophy bucks are also found in these fertile bottomland forests. There are vast numbers of reptiles and amphibians in bottomland ecosystems and many of the furbearers make frequent use of these riparian zones.

LOSSES OF RIPARIAN HABITAT

Although riparian ecosystems are still extremely important fish and wildlife habitat, exploitation and development of these systems have had serious impacts on fish and wildlife resources. Riparian zones were frequently the first areas settled by European immigrants. Rivers and fertile river valleys provided the abundance of fish, game, and other easily harvestable natural resources needed by settlers until they could bring lands into production. Rivers provided the only means of transporting large quantities of supplies and goods. Water power was harnessed to grind grain, saw wood, and accomplish other needed functions. The same fertile, alluvial soils that provided such excellent wildlife habitat also provided excellent farm lands after they were cleared of their dense forest stands, and water from the river was often used to irrigate croplands during times of drought. The major difficulty experienced from living next to the river was the frequent flooding of farms and villages; however, early settlers were willing to accept and adjust to these occasional and somewhat predictable inconveniences in order to capitalize on the many assets that derived from their location.

As development continued, people began looking for ways to enhance riverine transportation; maintain or increase water supplies for agricultural, industrial, and urban uses; and protect crops, homes, and industries from flooding. Various combinations of draining, diking, diverting, leveeing, damming, and channeling were used to accomplish these goals, but with increasing protection came additional clearing and converting of natural riparian environment to other uses.

Initially, the impacts of man's alteration activities may have actually increased the production of wildlife resources along rivers and streams by increasing habitat diversity and total production. Those species of wildlife not adapted to the often extensive climax riparian woodlands benefited from the diversity created by patchwork clearing, and agricultural crops provided a preferred food for many species of wildlife. Thus, increased abundance and diversity of wildlife was often associated with early developmental activities. However, the cumulative impact of continuous development, land use changes, overgrazing, inundation, stream channel alteration, water diversion, and other modifications of the hydrologic regime, has resulted in adverse effects on fish and wildlife habitats. Where habitat changes have been especially severe, certain species of plants and animals have become increasingly scarce, threatened, or even endangered. Of the 236 species of plants and animals on the Department of the Interior's list of threatened or endangered species, 69 are directly or indirectly dependent upon riparian ecosystems. Twelve riparian habitat areas have been designated as critical habitats.

Losses of riparian forest lands and associated wildlife have been most dramatic in the West and Midwest because of the relative scarcity of these types and the tremendous demand man has placed on the water and land resources of these regions. Along the Sacramento River in California, croplands cover over 66 percent of the terrace lands that once supported riparian forests. Conversion has been close to 100 percent beyond the flood control levee. On the Colorado River, cottonwood communities have declined from an estimated 5,000 acres to only about 500 acres as a result of changing hydrologic regimes resulting from upstream impoundments. There are still some 2,800 acres of willow-cottonwood stands along the river, but most are invaded by salt cedar, an exotic introduction of much lower value to wildlife. Overgrazing in the riparian zone of western rangelands is an extremely serious problem as attested by the "Forum - Grazing and Riparian/Stream Ecosystems" conducted by Trout Unlimited just last month in Denver, Colorado.

Bottomland hardwoods in Missouri have declined by 96 percent. Along the lower Missouri River, at least 180,000 acres that were once part of a wide riverine floodplain have become valuable croplands as a result of constriction of the river by channelization and bank stabilization activities and changed hydrologic regimes resulting from upstream impoundment for flood control and navigation purposes. Lake Oahe alone on the upper Missouri in South Dakota has inundated 300,000 acres of land, including all riparian areas along a 200 mile reach of the river. Conversion of bottomland hardwoods to agricultural crops have exceeded 95 percent in some Mississippi delta counties in Arkansas.

Quantification of riparian ecosystem alteration has not been accomplished on a systematic basis throughout the United States, but it is probably reasonable to assume that from 70 to 90 percent of all natural riparian areas have been subjected to extensive alteration. Furthermore, alteration is continuing at a steady pace. Overgrazing and water diversions in the West, stream channel alteration in the Prairie States, urban and industrial expansion in the East, and drainage and forest land conversion in the South; all these activities and more are eating away at the few still relatively undisturbed riparian ecosystems. Nowhere is this more dramatically illustrated than in the delta hardwoods of Mississippi where bottomland woodlands were reduced by 60 percent from 1970 to 1976.

CURRENT ACTIVITIES OF THE FISH AND WILDLIFE SERVICE

Protection of riparian systems has high priority in the programs of the Fish and Wildlife Service. The Service's role in riparian protection involves three main lines of activity: land acquisition; participation in the environmental planning and regulatory process; and conduct of research, studies, and inventories. Fish and Wildlife Service involvement in riparian protection originally stemmed from the agency's responsibilities for protection and management of migratory birds, particularly waterfowl. However, as both public environmental awareness and the Service's own responsibilities have broadened, its programs have reflected concern for the full range of environmental values inherent in protecting riparian ecosystems.

Land Acquisition

The Fish and Wildlife Service has about 35 million acres in National Wildlife Refuges and Waterfowl Production Areas which it acquired under one or more of the following authorities: The Migratory Bird Conservation Act of 1929; the Migratory Bird Hunting and Conservation Stamp Act of 1937; the Wetland Loan Act of 1961; the Land and Water Conservation Fund Act; as mitigation for Federal water development projects; and other legislative provisions. Many additional thousands of acres also have been acquired by the States through the Federal Aid in Wildlife Restoration Program. Lands acquired by the Service through the Migratory Bird funds are for waterfowl breeding, migration, and wintering areas. The Land and Water Conservation Fund has been used to acquire unique ecosystems such as those supporting endangered or threatened species or having other important natural resource values.

While most of the lands currently within the National Wildlife Refuge System are not riparian ecosystems, many refuges do contain sizable quantities of riparian lands. Examples are the White River Refuge in Arkansas, the Santa Ana Refuge on the Rio Grande in Texas, the Havasu Refuge on the Colorado River in Arizona, the Columbia White-Tailed Deer Refuge on the Columbia River in Washington, and the Upper Mississippi River Wildlife Refuge. All of these are largely riparian areas that benefit many species of fish and wildlife.

Current and planned acquisitions with Migratory Bird and Land and Water Conservation Funds will include many riparian lands. As part of an accelerated waterfowl acquisition program currently underway within the Fish and Wildlife Service, major Migratory Bird Fund acquisition efforts are being initiated in key waterfowl wintering areas; a 21,000 acre tract on the upper Ouchita River in Louisiana has just recently been purchased. The Service is also currently in the process of identifying unique ecosystems for each State. Initial identification should be completed by the end of the year. From these assessments, national priorities will be established to guide the Service in its Land and Water Conservation Fund acquisitions. Many of the areas being identified by this process are riparian ecosystems, especially those in the Southeast and the Southwest. Land is presently being acquired for the Minnesota Valley Wildlife Refuge and plans are underway to acquire lands along the lower Suwannee River in Florida with Land and Water Conservation Funds.

In perhaps the most ambitious effort ever proposed by the Fish and Wildlife Service to protect valuable riparian lands threatened by development, the agency has recently advanced a proposal to acquire 443,000 acres of the lower Atchafalaya River floodplain for the purpose of flood control, fish and wildlife conservation, and public recreation. This proposal advocates the purchase of the floodplain by the Federal Government as part of a multiple purpose plan to protect existing environmental values while providing a floodway for passage of excess floodwaters from the Mississippi and Red River drainages.

The estimated purchase price of this area is $85 million. However, the fish, wildlife, and recreational resource values of the lower Atchafalaya floodway alone are estimated to be approximately $97 million annually. At lease 300 species of birds, numerous mammals, 65 species of reptiles and amphibians, and 90 species of fish, crawfish, crabs, and shrimp occupy the floodway. When continuing values for flood protection, pollution abatement, and other natural resource functions are included, maintenance of this riparian system becomes even more important. Unless the floodway is protected and managed to sustain these resources, the Atchafalaya floodplain will be cleared and converted to agricultural crops, as have millions of acres of other Delta hardwoods.

Participation in Environmental Planning and Regulation

Even under the most favorable prospects, only a small portion of the riparian areas meriting protection will be subject to direct Federal acquisition. The majority of these areas will depend upon other means of protection from development or degradation. Thus, participation in the environmental planning and regulatory process is another important component of the Service's role in wetlands preservation.

Fish and Wildlife Coordination Act Activities

The principal authority for the Service's program in environmental planning and regulation is the Fish and Wildlife Coordination Act. Through the authority of the Act, the Service evaluates the impact of federally funded, permitted, or licensed water resource development projects and recommends measures for the mitigation and/or enhancement of fish and wildlife resources in conjunction with the development project. In response to this legislative mandate, the Service has become deeply involved in

consulting on and reviewing water and related land resource development proposals, both those which are federally financed and authorized by the Congress and those which are private and require issuance of a Federal permit or license.

These projects run the gamut from large water resource development projects constructed by the Bureau of Reclamation and Corps of Engineers to private construction of small structures such as docks and piers in navigable waters under Federal permits. Water resource projects proposed by public or private agencies which require Federal permits or licenses under the Coordination Act include construction activities in navigable waters; construction of hydroelectric power projects; fossil and nuclear-fueled power plants involving water diversion or transmission lines; discharge of pollutants; and discharge of dredged or fill material into wetlands. These actions are regulated by the U.S. Army Corps of Engineers, the U.S. Coast Guard, the Federal Energy Regulatory Commission, the Environmental Protection Agency, the Nuclear Regulatory Commission, and others. Many of these activities are prime causes of loss or modification of riparian systems, and it is through its implementation of the Coordination Act provisions that the Service has worked to prevent this.

It is important to remember that regardless of the action being taken, whether it be by Federal, other public, or private entity, and regardless of which agency ultimately issues the license or permit, the Service can only advise of the consequences to fish and wildlife and recommend measures to prevent damage, or when appropriate, to improve fish and wildlife resources. The Service has no enforcing power, except in those few cases where the proposed actions would take place on Service-administered lands. Its role under the Coordination Act is an advisory one. In the case of Federal projects proposed by the Corps of Engineers or the Bureau of Reclamation, the Service's advice, in the form of a Coordination Act Report, must be made a part of the request for project authorization and transmitted to Congress. Where permits are involved, the Service's comments are made part of the documentation reviewed by the decisionmaking official.

However, we have developed a strong, positive working relationship with various construction and regulatory agencies. Particularly since the advent of the National Environmental Policy Act, we believe that the Service's recommendations have carried increasing weight and that this advice has been instrumental in saving thousands of acres of wetlands and riparian areas from destruction. For example, recently concluded joint SCS-FWS channelization guidelines should do much to facilitate Fish and Wildlife Service input into future small watershed projects.

These guidelines suggest methods for protecting stream and riparian ecosystem resources in small watershed management activities. Channel modification and destruction of streamside vegetation will normally be considered only as a last resort under the guidelines.

In addition to providing national policy direction, which has helped assure that the Service's views concerning Federal activities would receive greater consideration, NEPA has added an additional dimension to the Service's advisory activities. The Act covers a wide array of development projects, beyond the water projects traditionally reviewed by the Service. By participating in Department of the Interior's review and comment on impact statements, the Service is able to work with numerous other Federal agencies to advise them on ecological values and environmental protection needs.

The President's recent Executive Orders on Protection of Wetlands and Floodplain Management provide additional policy guidance to Federal agencies, which should further strengthen the importance of the Service's recommendations. These Executive Orders specfically direct Federal agencies to avoid, to the extent possible, long and short term adverse impacts associated with the destruction, occupancy, or modification of wetlands and floodplains by direct or indirect developmental activities wherever there is a practicable alternative.

Better analytical methods can also contribute to more effective consideration of habitat protection needs in project formulation. To quantify changes in fish and wildlife habitat values resulting from water resource development projects, the Fish and Wildlife Service in concerted efforts with State Game and Fish agencies, private conservation groups and other Federal agencies has developed, and is continuing to refine, Habitat Evaluation Procedures. These procedures combine habitat quality and quantity values into an index that provides decisionmakers with a method of assessing existing habitat conditions, evaluating the consequences of alternative sites and plans, and determining compensation requirements. Development of these procedures to date has focused primarily on assessing habitat values in riparian areas that will be impacted by

water resource development activities. Thus, these procedures provide an important analytical tool for dealing with riparian issues.

Another technique being developed by the Fish and Wildlife Service in cooperation with other Federal and State agencies to assess impacts of stream alteration activities on fish and wildlife is an incremental methodology for physical instream habitat evaluation. This methodology allows quantification of potential habitat available for various species of fish at different streamflow regimes with different channel configurations and slopes. Through some modifications presently being considered, the incremental methodology may be useful for quantifying effects of stream alteration activities on riparian as well as instream habitats.

Environmental Planning

Recognizing that the best way to minimize environmental impacts is through input early in the planning process, rather than after a project has been formulated, the Service has sought to increase its planning involvement in various ways. Two of these, which are particularly germane to riparian protection, will be mentioned here.

The first of these is coastal zone management. Increasingly, the Service has been assisting States in the development of their programs under the Coastal Zone Management Act by providing guidance which will preserve important fish and wildlife habitats such as those in coastal floodplains. We are also participating in the Federal review and approval process for State coastal zone management programs.

The second involves Fish and Wildlife Service participation in water quality planning through Section 208 activities of the Clean Waters Act. The development and implementation of "Best Management Practices" to control non-point sources of pollution will have a strong positive influence on riparian resources along smaller streams and tributaries in agricultural areas. Best Management Practices incorporate those soil and water conservation measures that help to keep water where it falls, restrict soil erosion, and keep sediment and chemical pollutants out of the stream. Research indicates that natural streamside vegetation can reduce sediment transport from the uplands to the stream, that nearstream vegetation will moderate water quality problems associated with temperature, and that allowing streams to maintain a natural morphology will reduce bank erosion and suspended sediment concentrations by dissipating stream energy. Best Management Practices that incorporate the maintenance of riparian vegetation and natural stream morphology will not only reduce soil erosion and improve water quality, but will preserve and enhance fish and wildlife resources.

Endangered Species Act of 1973

The Endangered Species Act of 1973 has special importance to the planning processes of all Federal agencies. All Federal agencies are required by the Act to consult with the Fish and Wildlife Service when their activities or programs may affect endangered or threatened species or their critical habitats. Critical habitats are determined by the Service after consultation with the affected States. Once this critical habitat has been delineated, all agencies must insure that actions authorized, funded, or carried out by them do not jeopardize the continued existence of threatened or endangered species or result in the destruction or modification of this habitat. At this time there have been 34 final determinations of critical habitats, 12 of which involve riparian ecosystems. The only two plant species for which critical habitats have been designated are both located in unique riparian sand dune areas in the Sacramento-San Joaquin floodplain.

Research, Studies, and Inventories

As discussions at this Symposium have highlighted, a central aspect of any national effort must be development of information necessary for riparian protection and management. Information concerning the relative values, sensitivities and importance of various riparian areas will become even more crucial as developmental threats and pressures increase in future years. The Fish and Wildlife Service has been heavily involved in development of such information and expertise.

National Wetland Inventory

The National Wetland Inventory of the Fish and Wildlife Service is inventorying, mapping, and determining status and trends of those portions of riparian ecosystems classified as wetlands. However, some riparian areas, such as the transition zones along western streams or some areas of bottomland hardwoods in the East, have not been classified as wetlands and will not be included in the Wetland Inventory data base.

Research and Field Investigations

Research is being sponsored or conducted on many issues relating to management of riparian systems. Of particular interest to the topic of this Symposium is a program of research on the impacts of stream channelization and other alterations on stream ecosystems.

About 15 research projects are nearing completion or have recently been completed. These studies were conducted by various Fishery and Wildlife Cooperative Research Units and through contracts with universities and private consultants. Results of some of these projects have been presented at this Symposium. Studies in this program include investigation of the fish and wildlife values of national riparian ecosystems; impacts of stream alteration activities on land use changes, habitat values, and fish and wildlife populations in riparian areas; development of remote sensing techniques to monitor changes in riparian areas; dynamics of bottomland hardwood growth patterns under changing hydrologic conditions and assessments of the effects of altered stream flows on fish and wildlife in riparian ecosystems.

In addition to research studies, conducted for the purpose of increasing general understanding of riparian systems, numerous field investigations are being conducted by the Fish and Wildlife Service, often in concert with other Federal agencies, to assess the impacts of specific development projects. Field studies include investigations of riparian habitat changes on the Platte River where instream diversions are resulting in encroachment of riparian vegetation on sandbar habitats used by thousands of ducks and geese, sandhill cranes, and the endangered whooping crane as a staging area during migration. Other studies include rates and causes of riparian habitat losses on the Mississippi River as related to water resource development activities, effects of fluctuating water levels on riparian vegetation on the Columbia River, and estimates of fish and wildlife values of Atchafalaya floodplain habitats. While these and other studies are being conducted to determine site-specific solutions, usually directly in support of the Service's efforts to protect these areas under the Fish and Wildlife Coordination or Endangered Species Acts, they are also contributing greatly to our overall understanding of riparian systems.

For example, a special effort has been initiated in the Service's Southwestern Region to facilitate consideration of fish and wildlife needs in the riparian area. A five-member Riparian Habitat Team has been formed to develop and test strategies and techniques for the protection and enhancement of riparian ecosystems. The Team has a broad background in terrestrial and aquatic ecosystems with extensive experience in Federal water project planning. The Team is currently in the process of identifying and inventorying valuable riparian resources; developing alternative strategies to supplement traditional Fish and Wildlife Service efforts to protect riparian habitats; and supporting, through contracts, efforts to develop methods for reestablishing riparian vegetation.

PROGRAMS NEEDED TO PROTECT RIPARIAN ECOSYSTEMS

Although there are no legislative authorities specifically addressing riparian ecosystems as such, there are mechanisms for achieving reasonable levels of protection through existing floodplain, wetland, coastal zone, water quality, soil and water conservation, endangered species, wild and scenic river, and other environmental legislation. Despite this protection and the multitude of State and Federal programs developed in response to these legislative mandates, natural riparian ecosystems continue to be destroyed and degraded. Among the reasons for this continuing environmental degradation are economic pressures and programs that encourage conflicting uses, lack of public awareness of the important values associated with the maintenance of healthy riparian ecosystems, and failure of governmental agencies to fully implement environmental regulations and guidelines.

It is clear that if we are to reduce future losses and protect the increasingly precious remaining riparian systems, a concerted effort must be mounted. In our judgment, that effort should include the following measures:

1. First, we must strengthen our research, surveys, and inventories to build a better information base on riparian systems and their management. This includes:

   a. Better documentation of the multiple values of riparian ecosystems, including the contribution these systems make to flood control, pollution abatement, erosion control, streambank stabilization, waste treatment, ground water recharge, fish and wildlife productivity, recreation, and aesthetics.

b. Identification of functional relationships of riparian systems relative to biological, chemical, and physical interaction of water, soils, plants, and animals. From the standpoint of fish and wildlife resources, it is particularly important that we obtain better information on the area, shape, and characteristics of riparian habitat necessary to support various species and populations, and the extent to which they can tolerate habitat disturbance.

c. Development of mitigation methods, such as improved techniques for reestablishing riparian plant communities in disturbed areas to enhance fish and wildlife values.

d. Identification of riparian ecosystems where particularly important fish and wildlife resource values still exist, as well as those where potential for the reestablishment of such values is high.

2. Next, we must provide information to the public, planners, and decisionmakers, to increase their awareness of riparian values. We need public recognition and support of these values equivalent to that which has developed for coastal ecosystems in recent years and has resulted in effective action to reduce coastal wetland loss. In the long run, unless the public comes to recognize and support the value of riparian ecosystems, many of these areas will continue to be lost.

3. Third, we need to work towards a more vigorous and effective mobilization of the various tools of environmental planning and regulation already available. We have been provided with many of the necessary mechanisms; now we must use them effectively. For example:

a. The Clean Waters Act of 1977 provides major opportunities for protecting riparian systems, particularly through Sections 208 and 404 and through the implementation of Best Management Practice provisions relating to non-point sources of pollution. The Rural Clean Water Program being developed by the Department of Agriculture will have special significance to riparian problems on privately owned agricultural lands.

b. Effective compliance with President Carter's Executive Orders 11988 and 11990 on Floodplain Management and Protection of Wetlands issued last year will be a major step forward, with respect to Federal and federally supported projects. These orders specifically charge all Federal agencies to restore and preserve the natural and beneficial values served by floodplains and wetlands.

c. In June 1978, the President delivered to the Congress water policy initiatives designed to improve the efficiency in planning and management of Federal water resource programs, provide a new national emphasis on water conservation, provide more Federal-State cooperation in State water resource planning and, give more attention to environmental quality. Attention to these improvements will do much to resolve problems in riparian ecosystems. Five of the suggested initiatives have special significance to protection of riparian ecosystem values. These are:

a. Requiring the explicit formulation and consideration of a primarily nonstructural plan as one alternative whenever structural water projects or programs are planned.

b. Requiring that mitigation funds for fish and wildlife damages be provided concurrently and proportionally with construction funds.

c. Requiring that States and Federal agencies give special attention to protecting and managing groundwater and maintaining instream flows needed for fish and wildlife.

d. Requiring that the Departments of the Interior and Commerce promulgate regulations and other Federal agencies prepare formal procedures for implementing the Fish and Wildlife Coordination Act.

e. Requiring that the SCS give full consideration to the stream channelization guidelines in small watershed projects, insist that land

treatment measures be accelerated in conjunction with structural methods, and implement post-project monitoring to assure compliance with recommended land treatment measures.

4. Acquisition, or other special protection of especially valuable and highly threatened ecosystems will be required, including:

   a. Continued acquisition by the Fish and Wildlife Service as part of the National Wildlife Refuge System. For example, protection of important riparian areas in the arid Southwest and in southeastern bottomlands has high priority in the Service's acquisition program.

   b. Acquisition by State and private organizations, such as the Nature Conservancy and Audubon Society. In this regard, the National Heritage Program being developed by the Heritage Conservation and Recreation Service, and involving a coordinated network of State heritage programs, could be an especially valuable tool.

   c. Inclusion in the Wild and Scenic Rivers System. This is another important mechanism for protecting particularly valuable riparian habitats. Fortunately, the National Parks and Recreation Act of 1978 added 8 new rivers to the system, as well as including 17 new rivers to the study list as potential candidates.

5. In the final analysis, however, many riparian ecosystems are likely to remain in private hands where economic inducements to convert them into agricultural and other uses will be great. Existing environmental controls are generally not an effective mechanism for addressing changing land use patterns such as these. New strategies to discourage destruction of key riparian areas should be explored. These might include imaginative use of land use zoning mechanisms and various tax incentives to encourage protection.

   One new approach is the Department of the Interior's Area of National Concern concept, which recognizes that there are large areas of valuable resources where the best solution to protection is to focus the combined resources and capabilities of local, State, and Federal governments and the private sector in developing a long-term comprehensive management plan for natural resource protection and enhancement. Two criteria are involved in the Area of National Concern approach:

   a. That the resource involved is of sufficient national concern to merit some Federal participation beyond that of the Land and Water Conservation Fund program; and

   b. That the resource, even though it has intrinsic national quality, should not be included in the traditional park, forest, or refuge systems due to excessive cost of purchasing the vast amount of land necessary to protect the values of the area, management considerations, or other factors.

   The idea is to avoid Federal acquisition and to exploit existing local, State, and Federal protection tools and incentives wherever possible. This concept is first being applied in New Jersey's Pinelands and might well be applied to other systems in the future.

In outlining the above program of action, we have not limited ourselves to responsibilities of the Fish and wildlife Service. On the contrary, we recognize that our agency alone can only do a small part of the job. However, in working with the National Park Service and the many other agencies and organizations which co-sponsored this Symposium, we in the Fish and Wildlife Service were encouraged by the tremendous interest and support expressed for protection of riparian ecosystems.

Hopefully, the spirit of cooperation that has made this Symposium possible will carry over into the development of interagency strategies for addressing land and water resource needs that maintain, as far as possible, the functional integrity of riparian systems.

Position Paper:

Soil Conservation Service and Riparian Ecosystems: A Long-Term View[1]

Victor H. Barry, Jr.[2]

Abstract.--The Soil Conservation Service, USDA, has a long history of promoting the preservation, management, and enhancement of riparian ecosystems in ways that are in balance with the Nation's total needs. Through SCS's voluntary action programs, it helps individuals and governments develop and implement plans that protect riparian ecosystems.

The Soil Conservation Service supports the proposition that riparian ecosystems should be preserved, maintained, and managed in ways that are in balance with the Nation's total needs. The Service has a long history--confirmed by policy, procedures, and actions--corroborating that position.

The Soil Conservation Service views the riparian ecosystem issue as part of larger land use issues facing the Nation. In Secretary's Memorandum No. 1827, Revised October 30, 1978, Bob Bergland said:

"Environmental, economic, and social needs and related land use decisions are matters of concern to the Department of Agriculture. Decisions concerning land use arise from needs to maintain and stimulate economic development, maintain and enhance agricultural, rangeland, and forest production capabilities, provide or improve community services, facilities, and living space; to preserve the natural environment and associated wildlife and recreational values; and to assure adequate supplies of high-quality water. These needs are highly interdependent and often competitive for the limited supply of available and suitable land."

It is Departmental policy ". . . to recognize and respect the rights and responsibilities of landholders in making private land use decisions, and the rights and responsibilities of State and local governments in developing public policies regarding non-Federal land use." Thus, the SCS deals with land use primarily in the context of the rights of private individuals to make and implement decisions about the use and treatment of land and water resources they own.

People voluntarily participate in SCS programs. We cannot force them to do anything, although we can put some constraints on what happens in project-type activities. We attempt to guide decisions and actions through technical assistance that is objective, balanced and rational and is based on an understanding of people and their environment.

The Soil Conservation Service has four main action programs that affect riparian ecosystems: Conservation Operations, Small Watershed Protection and Flood Prevention, Resource Conservation and Development, and River Basin Studies and Investigations. You may be most familiar with and hear most about--the Small Watershed Program. Yet riparian ecosystem policy of the Soil Conservation Service has evolved primarily through the Conservation Operations Program. Thus, a discussion about it in some detail will help you more fully appreciate our position.

CONSERVATION OPERATIONS PROGRAM

The Conservation Opertions Program consists of:

-- Technical assistance in planning and applying conservation programs on both public and private land;

-- Making and interpreting soil surveys;

-- Identifying, selecting, and learning to culture, grow, and manage conservation plant materials;

-- Inventorying and monitoring the use and treatment of soil, water, and related plant resources; and

-- Making water supply forecasts.

[1]Paper presented at the Symposium, Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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The "sub-programs" require many specialists in biology, forestry, range management, agronomy, hydrology, limnology, economics, and soil and engineering sciences.

Today, I would like to focus primarily on the technical assistance aspects of our Conservation Operations Program.

Conservation Technical Assistance is basic. Through it, SCS provides conservation planning and application help to more than a million individuals each year. Over a 2- or 3-year period, we help individuals who control conservation decisions and actions on almost ¼ billion hectares. Each year, we help more than 25,500 governmental agencies with soil and water resource use and treatment decisions. Each year, we review more than 20,500 private enterprise development plans for planning commissions or permitting agencies. Each year, we provide them with 14,500 different inventories and interpretations.

Obviously, Conservation Technical Assistance can directly or indirectly affect most privately owned riparian ecosystems of the United States. Our ability to affect them favorably, however, is directly related to our ability to convince decisionmakers that they are important.

To understand the magnitude of the problem, consider the extensive shifts in cropland use alone that have occurred. According to the recent "Potential Cropland Study" (Soil Conservation Service, U. S. Department of Agriculture, Statistical Bulletin No. 578) since 1967, about 79.2 million acres have gone out of cropland while another 48.7 million acres have come into cropland use during the same period; a net loss to cropland of 30.5 million acres. Each year, since 1967, about 600,000 acres of cropland become urban and built-up areas. About 24 million acres are currently being held for urban use. These kinds of land use changes put pressures on riparian ecosystems in one way or another.

Over the years, Soil Conservation Service policy has responded to public concerns about wildlife habitat. This has helped to shape our activities affecting riparian ecosystems. The first policy statement about the place of wildlife habitat conservation in SCS programs was Field Memo. 188 in 1935. It did not mention wetlands and drainage. However, later, in 1939, Field Memo. 868 said, "Under no circumstances shall such work (meaning drainage and irrigation) be undertaken for the sole purpose of reclamation nor under conditions which will tend to keep lands of low fertility or lands of submarginal character in cultivation . . . Drainage plans shall give proper consideration to wildlife conservation." Obviously, this included wetlands; yet today we would not speak of wetlands as submarginal because our growing knowledge about them indicates they are tremendously important for many reasons.

In 1947, Field Memo. 1120 said, "In our activities in drainage planning and application, we must always remember to caution soil conservation districts and farmers and ranchers against draining any considerable area of land which is better suited for wildlife than for cultivation . . ."

These early policy views tended to subordinate wildlife habitat and wetland preservation policies to agricultural development. Yet, in the context of the times, they were rather remarkable.

About 1950, we identified an emerging population explosion. We spoke of it as "a fifth plate." That meant agriculture had to expand to feed an average family of five instead of four. That was the wisdom of the times 28-30 years ago. Even so, SCS tried to establish realistic policies that recognized wildlife habitat values. Little did we know about the "agrotechnology" and "agrobusiness" explosion yet to come. In less than 10 years, production exceeded demand. We found we didn't have to worry about that "fifth plate" in the United States. Surplus commodities accumulated.

In the fifties, it was time to think in terms of reducing agricultural production. So, SCS BIOLOGY MEMORANDUM-2, adopted in 1956, prohibited SCS from giving drainage assistance in order to bring new land into production. This same policy became a part of the provisions for cost sharing under the Agricultural Conservation Program. Other programs were authorized to help with an orderly and safe reduction in agricultural land. To help achieve this mission, the Soil Bank Program, Great Plains Conservation Program, and wildlife habitat cost-sharing practices under ACP emerged.

During the late fifties and early sixties, the Soil Conservation Service refined and shaped its drainage policies, paying particular attention to the "pothole" issues of the northern Great Plains. Out of the "pothole" issue grew the USDA Water Bank Program. SCS had a major role in its development. The basic outline of the authorizing legislation was developed jointly by Norman Berg now Soil Conservation Service Associate Administrator, and others from the Fish and Wildlife Service. I had the pleasure to share in interpreting the legislation and designing the program. Over the years, we have provided the technical

planning and application assistance needed to make the Program effective. We are proud of that Program and are pleased to support it in both concept and practice.

In the early 1970's, the U. S. began to feel the effect of its past energy policies. Oil imports accounted for most of our total supply. The OPEC Nations raised prices. The U. S. decided to expand agricultural exports in order to offset high import costs for oil. The agricultural policy became "farm fencerow to fencerow." High production was encouraged. Marginal land was brought under the plow once more . . . floodplains were cleared and drained . . . drainage was improved on existing farmland.

The Soil Conservation Service was alarmed. A philosophy and a slogan of "Produce More - Protect More," was adopted. The policy was expounded in rural and urban news media throughout the Nation. We accelerated efforts to stem the tide bringing marginal grasslands, floodplains and wetlands into production.

Still, we could deal with people only on a voluntary basis. Where we could not discourage bringing new land into production, we tried to assure good land treatment in order to minimize adverse effects.

Drainage policies developed over almost 35 years were suddenly inconsistent with Department policies. The Soil Conservation Service immediately initiated development of a new policy which would help to strike a balance in the use of wetlands. In late 1973, Lawrence Compton, SCS, Chief Biologist, and I put together what became SCS wetland policy two years later under Administrator R. M. Davis. That policy, while not as stringent as some people might prefer, has helped preserve wetlands. In general, we do not provide technical or financial assistance for draining wetland types 3 through 20, as defined in USDI's Circular 39. We are proud of our SCS wetland policy statement. We feel we have been in the forefront of the Federal agencies whose programs were addressed by the President's Executive Order 11990 on preservation of wetlands. Similar drainage policies have now been adopted by the Congress and applied to the ACP.

Most (58 percent) of the U. S. is privately owned; thus, we face a tremendous challenge to get fish and wildlife management practices incorporated into resource management systems on private lands. It is the policy of SCS to encourage and help private landowners plan and implement systems that will accomplish that end. This has been expressed in BIOLOGY MEMORANDUM-1 since 1956. More broadly, it is the Department of Agriculture land use policy to: "Advocate the retention of Important Farmlands and Forestlands, Prime Rangeland, (and) Wetlands, . . . whenever proposed conversions are (1) caused or encouraged by actions or programs of a Federal agency; (2) licensed by or require approval by a Federal agency; or (3) inconsistent with local or State government plans, provisions will be sought to assure that such lands are not irreversibly converted to other uses unless other national interests override the importance of preservation or otherwise outweigh the environmental benefits derived from their protection. In addition, the preservation of farmland in general provides the benefits of open space, protection of scenery, wildlife habitat, and in some cases, recreation opportunities, and controls on urban sprawl."

As a result of SCS conservation technical assistance, through 3,000 offices there are now about 2.2 million ponds in the countryside. The number increases by about 45,000 per year. These ponds provide at least 170,000 miles of shoreline. We estimate that more than 4 million hectares of wetlands are being managed for wildlife and other values as a result of SCS conservation technical assistance. Another 44½ million hectares are managed as habitat for upland wildlife. Streams passing through these areas, and wetlands and ponds surrounded by them, contribute to the vitality of riparian and aquatic ecosystems.

Historically, SCS has encouraged protection and preservation of riparian ecosystems. Not showing up in the "progress" records are fences placed by farmers and ranchers to protect streambanks and control cattle crossings; plantings made to protect streambanks; and other helpful practices. The usual center of attention has been rock/riprap and other devices to protect streambanks. Yet, SCS continues to promote and emphasize the importance of riparian ecosystems.

Just recently, we took steps to reemphasize the importance of stream corridors in their natural state. We are concerned that agricultural, urbanizing, forestry, flood control and other activities have impacted adversely on riparian ecosystems. SCS has been an innovator and played a major role, for example, in helping to plan stream corridors in Connecticut.

Through our Plant Materials Centers we have identified and developed many plants that can help restore damaged riparian ecosystems. Famous among them on the east coast is 'Cape' American Beach grass. Not so well known but equally promising is 'Streamco' purpleosier willow, developed by our Big Flats, New York,

Plant Materials Center. It is now available to commerical nurserymen and is being used to protect streambanks in New England, New York, Pennsylvania, and Michigan.

Sometimes our assistance pays surprising dividends. In Florida, Mr. and Mrs. W. H. Fitzpatrick asked SCS in 1964 to plan an 18-hectare pond on their farm in Hardee County. The job was routine except that they wanted to preserve two stands of pondcypress. This took some special work to provide for the fluctuating watertable that pondcypress needs. The Fitzpatricks stocked the pond with fish. Herons, egrets, and white ibis began roosting and nesting in the trees. In 1968, a colony of woodstorks arrived, built 25 nests, and raised their young. The woodstork is on the Florida list of endangered wildlife species.

SCS also has featured the importance of the Nation's wetlands and riparian ecosystems through many publications, news releases, feature stories, speeches and slide presentations. These efforts likewise have resulted in maintaining viable riparian ecosystems, and better public understanding of the issues involved.

SMALL WATERSHED PROGRAM

Passage of Public Law 566 by the 83rd Congress in 1954 provided a means for dealing with soil and water conservation problems occurring on a scale too large for an individual to solve. It is a project approach to conservation problem solving.

Small Watershed Program policies affecting riparian ecosystems, especially wetlands, kept abreast of those in the Conservation Operations Program. BIOLOGY MEMORANDUM-2, applied to small watershed projects as well as all other SCS programs. It prohibited drainage to bring new land into production and remained in effect until 1975, when it was replaced with CONSERVATION PLANNING MEMORANDUM-15.

Avoiding drainage for bringing new agricultural land into production did not, of course, cover the entire range of issues about riparian and aquatic ecosystems. Stream channels were being modified or restored to control floods. They became an often painful environmental issue for many of us. Thanks to forthright concern by many people and groups, we have addressed the issue squarely. Today, the "Channel Guidelines" developed jointly by the SCS and Fish and Wildlife Service help both agencies and project sponsors make wise decisions about the use and alteration of stream channels.

SCS has high regard for the NEPA process. It brings us into dialogue with most parties interested in watershed projects. The NEPA process, our own policies and the "Channel Guidelines" help us work together toward a balanced solution to resource problems.

Some watershed projects have had adverse impacts on riparian ecosystems; you and others have called the impacts to our attention. Other watershed projects, though, have been and are being designed to conserve riparian ecosystems.

The Little Black River Watershed Project in southern Missouri is a good example of how environmental considerations influenced the watershed plan and engineering designs. Three major environmental concerns were identified during planning:

-- Maintaining the natural channel on the lower Little Black River and the ecosystem associated with it.

-- Preserving the hardwood forest habitat in the delta and its diverse wildlife.

-- Maintaining or improving the fishery habitat in manmade ditches in the delta and along the Little Black River.

The Delta of this river had been cleared and drained between 1910 and 1930. The delta lands have flooded as many as four times a year. Annual damage to crops has been a million dollars or more. Our responsiblity was to help local project sponsors find a way to provide the flood protection desired while preserving, maintaining, and improving the remnants of the once extensive riparian ecosystem.

The watershed plan includes several measures to reduce the deterioration of the natural river channel through the delta. There will be 25 structures to retard floodwater and reduce peak flows of water. Four dams will be built across scour channels to prevent the river from being directed down the drainage ditches. A bypass floodway with a water control structure will maintain bankful flows in the river and divert excess flows down the floodway.

The watershed plan also will help protect what is left of the area's forests. From 1830 to 1900, almost all the forest cover was removed. Channels made to float logs to the sawmill later became the drainage ditches used to convert the land to agriculture. Today, only 7 percent of the delta is forested--mainly in small tracts, but some areas range up to 300 acres each. The narrow strips of swamp forest are critical for survival of native fauna that remain in the area. Construction

techniques will be altered to assure that the swamp forest habitat is preserved. Three oxbows will be preserved. Most importantly, the drainage districts sponsoring the project will obtain conservation easements to preserve these wooded areas and will purchase 100 acres of delta land to be used for wildlife habitat. This includes the last mature tract of shortleaf pines.

RESOURCE CONSERVATION & DEVELOPMENT PROGRAM

The Resource Conservation and Development (RC&D) Program in some ways is similar to the Small Watershed Program. One basic difference is that the objectives of an RC&D area are much broader than those of watershed projects. There are no program constraints on the type of activities that may be carried out within a multicounty RC&D area since they are locally initiated and administered. The only limitation by SCS is that the measures and activities for which SCS RC&D Program funds for coordination, technical assistance or financial aid may be used must be identified, consistent with program authorities, adopted and carried out by the local people. Projects range from preventing floods to enhancing outdoor recreation and fish and wildlife, encouraging new industries, to improving the environment in a variety of ways.

We strive hard to encourage all RC&D sponsors to consider the environment, both in broad objectives and in specific measures. Consensus on the means to achieve them is reached through the public participation process that is a basic part of the design of the RC&D Program.

Let me describe just one of many RC&D measures that affects riparian ecosystems.

In the Sussex-Warren RC&D Area, which encompasses northwestern New Jersey, sponsors are buying a 289-acre tract of riparian land. This land contains one of New Jersey's largest breeding colonies of the great blue heron. The great blue heron is on the State's endangered species list. The Lafayette Heronry, named after the nearby town, is one of only three such heronries in New Jersey. The sponsors of this RC&D measure are the Township of Lafayette and the Sussex County Soil Conservation District.

The tract will cost about $400,000, half of which will be RC&D funds. The area includes the heronry and a surrounding buffer zone. There are 162 acres of wetlands; the remaining acres are in upland habitat. The area also will serve as a refuge for other game and nongame animals. The area is being purchased because rapid residential development threatens destruction of the heronry.

RIVER BASIN PROGRAM

The River Basin Program is authorized by Section 6 of Public Law 566. River basin studies made by State, USDA, and other Federal agencies are long-range analyses of problem areas to provide a coordinated approach to problem solving. River basin studies also contribute to meeting our riparian ecosystem needs.

A good example is in Massachusetts. There the values of 235 separate freshwater wetland areas were evaluated by field teams for flood control, forest management, fish habitat, wetland wildlife habitat, recreation, uniqueness, and visual quality. Summary tables of the resource values were included in the Connecticut River, Central, and Coastal region reports. About 75 percent of the larger, regionally significant freshwater wetlands of the State were included. Coastal wetlands were not evaluated because they are all considered to have high resource value. The data developed provide State and municipal governments with a tremendously useful guide for acquiring and protecting the most important wetlands.

LOOKING AHEAD

We have looked at the past to examine the SCS policies affecting riparian ecosystems; but what about the future.

We are working on a number of things which will help to shape future policies. Most important among these are those activities authorized by the Soil and Water Resources Conservation Act (RCA) of 1977.

RCA provides "for furthering the conservation, protection, and enhancement of the Nation's soil, water, and related resources for sustained use." It is undoubtedly one of the most significant pieces of legislation affecting the resource conservation movement. The act will help give the 44-year old soil conservation program new direction and impetus.

Soil, water, and related resources will be continually appraised. Programs for furthering conservation, protection, and enhancement of these resources will be developed and updated. They will be consistent with the roles and programs of other Federal agencies and of State and local governments. Reports will be provided to Congress and the public. The public is being asked to help with identifying

national concerns and evaluate programs and ideas directed towards solving resource problems.

SCS is working with the Fish and Wildlife Service on two specific activities affecting riparian ecosystems. One is making an inventory of the wetlands of the Nation. The other is the development of a Habitat Evaluation Procedure.

The combination of these activities will impact heavily upon USDA and SCS program concepts. Since all USDA conservation activities will be examined under RCA, we will be able to look at the interconnection between programs such as those dealing with agricultural commodities, housing, and rural development. We will know more about prime and important wetlands and other prime lands for forest and agricultural activities. We will be able to assess habitats better and to design conservation measures which will contribute to a balanced use of resources. Through cooperative work with other agencies, we will understand and communicate with each other better than we have in the past. Through a continual data gathering and appraisal process, we will do a better job of monitoring the status of soil, water, and related resources.

We are just getting underway with the Rural Abandoned Mine Program (RAMP). Restoring abandoned mines will help to improve the condition of many streams by controlling sources of pollution. This cost sharing program with private landowners has as a condition for participation, that the landowner have a conservation plan for managing restored areas in an environmentally sound manner.

Final rules and regulations for the Rural Clean Water Program have been published. When funded, this cost-share program will be targeted to high priority areas for correcting nonpoint sources of pollution. This audience knows what impact that will have on riparian and aquatic ecosystems.

We are working on new program policies and procedures for small watershed projects to emphasize land treatment in order to reduce, wherever, possible structures that alter aquatic and riparian ecosystems. We are examining and hope to constrain the "216" emergency watershed protection program to give emphasis to nonstructural solutions to problems. You saw and heard an earlier presentation about that.

SUMMARY

The Soil Conservation Service has been among the leaders in helping to preserve, conserve, and manage riparian ecosystems. From the beginning of the soil and water conservation movement in 1935, we have progressively improved and broadened the scope of our policies so as to contribute to a reasoned and balanced use of natural resources. Our technical services have been used by millions of landowners and thousands of government units. Riparian ecosystems have been purchased or protected by law as a result of SCS help. Habitat for endangered species of animals and plants has been developed, protected, or preserved through SCS programs.

In a democratic society which reserves the right of the individual to decide the use of his own natural resources, great strides have been made in encouraging people to safeguard those resources voluntarily. We believe that this voluntary approach--combined with public incentives through government assistance programs--is the most lasting way to assure that the bulk of our Nation's riparian ecosystems remains functional.

We do believe that some critical areas need to be preserved by statute where elected officials and their constituents agree that is the proper course. We believe that all government agencies should carefully consider the impacts of their programs upon riparian ecosystems. In the Soil Conservation Service, we will continue, with the good help of you and others, to modify policies and procedures where needed to make our programs achieve the greatest good for all the people and all of the ecosystems entrusted to their care.

Position Paper:

The Position of the Bureau of Land Management on the Protection and Management of Riparian Ecosystems[1]

J. David Almand[2]
William B. Krohn[3]

Abstract.--This paper discusses the Bureau of Land Management's (BLM) policy and procedures for protection and management of riparian ecosystems. Past abuses of riparian habitats are recognized as are future opportunities for improved management. Recent legislative and executive mandates require land managers to protect the natural functions of riparian ecosystems. BLM is implementing a positive program to adequately protect and manage components of riparian ecosystems.

INTRODUCTION

The BLM is responsible for management of approximately 470 million acres, or about 20 percent of the Nation's land area. Almost 300 million acres of these public lands are in Alaska with most of the remaining 170 million acres in the 11 contiguous Western States. The location of most riparian areas, mostly in a semiarid region, adds to the uniqueness and the ecological value of these ecosystems.

In the semiarid West, riparian ecosystems are generally brushy plant communities which occur along watercourses. These areas have many public values and function as popular recreation sites, provide scenic variety, preferred road construction areas, productive grazing areas, and provide crucial habitats for wildlife. Riparian areas are used by a diversity of game and nongame wildlife, including many threatened and endangered species.

Available information reveals that only about four percent of the public lands in the Western United States consists of riparian or wetland habitats. BLM has estimated the acres and general condition of these habitats on western public lands, excluding Alaska, during Fiscal Year (FY) 1977 as follows:

	Total Acres	Acres In Need Of Management
Riparian	536,827	447,458
Wetland	373,728	190,463

We acknowledged that a high percentage of riparian ecosystems on public land in the West are in unsatisfactory condition, largely because of management capabilities to prevent excessive livestock grazing, road construction, and other activities. Water quality and quantity, flood frequency and severity, commercial and recreational fisheries, and a wide range of wildlife species have been impacted by these degradated riparian conditions. As a result, BLM is striving to implement positive riparian management activities in connection with livestock grazing and other Bureau programs.

Before we get into our policy and procedures for accomplishing better management of riparian ecosystems, let us first review BLM's mandates for maintaining, enhancing, and restoring these key ecological areas.

[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

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AUTHORITIES

The Federal Land Policy and Management Act (FLPMA) of 1976 provides the foundation for the recognition and proper management of riparian areas. Specifically, section 102(a)(8) requires that public lands be managed so that, among other factors, ecological and environmental values are protected. Additionally, this section recognizes the need to ". . . protect certain public lands in their natural condition . . . ;" and to ". . . provide food and habitat for fish and wildlife . . . ." Section 102(a)(11) of FLPMA requires the prompt development of regulations and plans to protect areas of critical environmental concern (ACEC). ACEC are defined in section 103(a) as ". . . areas within the public lands where special management attention is required . . . to protect and prevent irreparable damage to important historic, cultural, or scenic values, fish and wildlife resources or other natural systems or processes, or to protect life and safety from natural hazards." The Bureau has recently developed procedures to designate ACEC's. Due to the scarcity of these riparian areas on public lands and their importance in ecological processes, we anticipate that many such areas will be given special management attention and protection as ACEC's.

Other significant Federal legislation which influences BLM management of riparian ecosystems includes the Clean Water Act, the Fish and Wildlife Coordination Act, the Endangered Species Act, the Surface Mining Control and Reclamation Act (SMCRA), and the National Environmental Policy Act (NEPA). The latter two Acts are starting to have major impacts on BLM management of riparian areas. The SMCRA, for example, establishes standards which may exclude surface mining in alluvial valleys. Also, analyses regarding NEPA compliance is enabling us to identify major opportunities to adjust and regulate livestock grazing, mining and mineral development, and other uses of the public lands.

A new piece of legislation, the National Rangelands Improvement Act of 1978, will also prove to be a key piece of legislation in our efforts. Congress, for the first time, recognizes that the public lands are in less than desirable condition and that productivity is far below potential. The Act authorizes $365 million over 20 years for multiple-use improvements, 80 percent of which must be for on-the-ground improvements.

The President has also taken action to safeguard these valuable ecosystems. On May 24, 1977, President Carter signed two Executive Orders (EO) which directly relate to riparian ecosystem management on Federal lands. EO 11988, entitled Floodplain Management, provides a broad framework to protect the natural functions of floodplains. EO 11990, Protection of Wetlands, is more specific in that it mandates the protection of natural processes in wetlands, including wetlands occurring within floodplains.

We are now developing procedures to implement both Presidential EO's. Interim BLM procedures on floodplain management were published on September 28, 1978, in the Federal Register. Wetland protection procedures have also been developed. Both documents have been available for public review and comments will be incorporated as appropriate. We plan to issue final procedures on the management and protection of floodplains and riparian-wetland areas to all BLM field offices by the end of January 1979.

POLICY

There are four basic components to BLM's policy for safeguarding riparian ecosystems. These are:

1. To avoid, to the fullest extent possible, long and short term adverse impacts associated with the destruction, loss, or degradation of riparian areas.

2. To avoid the direct or indirect support of new construction in riparian areas whenever there is a practical alternative.

3. To preserve and enhance the natural and beneficial values of riparian areas which may include constraining or excluding uses causing irreparable damage.

4. To minimize all actions causing definable adverse impacts to riparian areas.

IMPLEMENTATION

Authorities and policies to protect riparian ecosystems are meaningless without procedures for on-the-ground implementation. The Bureau's environmental assessment and planning processes are the basic tools for doing the job. Here is how these processes relate to riparian ecosystem management on public lands.

Land-Use Planning

BLM's planning system is the long term means for resource and land-use inventory, protection, and management. Comprehensive land-use plans, called Management Framework Plans (MFP's), are prepared based upon resource inventory and other data obtained through an integrated information gathering process called the Unit Resource Analysis (URA). The resulting land-use plan identifies existing resources and uses and reflects administrative decisions which allocates resources to various uses. BLM's basic land units for planning and management are termed planning units. Presently, we have 569 planning units, and they average some 300,000 acres in size. Public participation is an integral and vital component throughout the Bureau's planning process.

To elaborate, a URA is developed for each of these planning units. It contains the results of resource inventories as well as a description of resource potentials. The MFP is then developed utilizing the URA and certain other planning documents containing economic and social information. Implementation of MFP decisions are then accomplished either (1) indirectly through stipulations and protective provisions in leases, licenses, and permits, or (2) directly by development and implementation of specific activity plans. Where riparian values are of special importance to wildlife, for example, a Habitat Management Plan (HMP) may be prepared to identify, guide, and evaluate management actions. BLM presently manages some 65,000 acres of riparian areas under the HMP's approach.

Environmental Analysis

Environmental analysis is the Bureau's primary method for implementing riparian protection over the short haul. Virtually every BLM action requires either (1) an environmental assessment record (EAR), or (2) an environment statement (ES). These evaluations are in accordance with NEPA requirements. EAR's are generally done to determine whether or not an ES is needed. Both types of environmental records can, and do, address specific measures needed to protect riparian ecosystems.

Specific Management Methods

Both the Bureau's planning and environmental analysis processes can result in recommendations for actions to enhance, maintain, or restore riparian ecosystems. Some of the specific means include: (1) rest rotation grazing, (2) protective fencing, (3) alternative water sources, and (4) establishment of buffer strips. Buffer strips, for example, are used on all BLM timber sales to protect streams and riparian areas in western Oregon. When the Bureau implements its wetland-riparian Manual in 1979, we plan to establish many buffer strips on other areas where riparian ecosystems need protection. The purpose of these buffer zones obviously is to protect, to the extent possible, riparian and wetland areas from significant disturbance (i.e., road or other construction, mining).

CONCLUSION

In FY 1977, approximately 65,000 acres of riparian habitat on BLM-administered lands in the West were under direct management. Unfortunately, this acreage compares to more than 440,000 acres needing management out of a total of more than one-half million acres of riparian habitat in the 11 Western States. Most of these riparian ecosystems are located on arid and semiarid rangelands. They are, therefore, of crucial importance to the health and well being of the ecosystems. Given the locations of riparian ecosystems and their critical natural functions, the need for proper management of these vital resources is magnified.

Recent legislative and executive mandates provide strong direction for riparian ecosystem protection and management on public lands. BLM's planning and environmental assessment processes, along with specific policies and management techniques, provide the framework and the means for adequately safeguarding these areas. BLM realizes that it has a big job ahead which cannot be done overnight. Nevertheless, BLM is dedicated to protecting and managing riparian areas on the public lands to the benefit of all Americans.

Summary:

A Summary of the National Riparian Symposium: A Proposal for a National Riparian Program[1]

J. Frank McCormick[2]

Importance of riparian wetlands and a growing awareness of this importance, are evidenced by the size and diversity of this audience. Well over 300 scientists, engineers, resource managers, and agency administrators represent ecology, hydrology, soil science, conservation, and resource development. You represent every region of the United States, state and local government, federal agencies, and environmental organizations with natural resource responsibilities. The composition of this audience, and presentations to this audience, are evidence of the scattered and diverse efforts under way to manage and protect riparian wetlands.

One goal of this symposium is to assess the status of knowledge of riparian ecosystems and their values. Once achieved, this goal is of limited value unless it serves as a basis for improved management strategies and policy development by land management agencies. A gentleman from the Office of Secretary of the Interior recently informed me that his 30 years of experience has caused him to conclude that symposia of this type are a waste of time. The emphasis should be upon field programs, where the action is. I wholeheartedly agree with his assessment, if we fail to use what we learn here to improve riparian habitat management and protection. In another sense, I argue with the gentleman's point of view. If agencies take blind action, initiated in ignorance of best available science and technology, or uncoordinated with goals of other projects within the same or different agencies, such action is inconsistent with the President's goal for increased efficiency, reduced cost, and conservation of resources. Such actions are, in large part, responsible for many of the pressures and problems threatening the survival of riparian wetlands.

On the basis of what I have learned here, I believe our understanding of the characteristics and values of riparian wetlands is sufficient to provide a basis for improved management strategies. It is clear that the severity of impacts upon riparian wetlands and the accerlerating rate of their destruction is sufficient to warrant strong policy statements by local, state, and federal agencies. Best available information indicated that we may already have lost as much as 90% of our nation's original riparian wetlands. We continue to lose the remainder at a rate of 6% per year. We all grow impatient as we lose an ecosystem of unusually high value, one upon which 3/4 of our breeding birds are dependent, upon which nearly 1/2 of our mammals are dependent, in which over 100 endangered species reside, and one which provides innumerable services to adjacent ecosystems. Now is an appropriate time for action. In spite of our best scientific endeavors, the best of our management strategies, and the strongest of our agency positions, we will continue to fail to achieve our goal if our efforts remain scattered, diverse and lack focus. A concerted national effort is required to achieve improved management and protection of riparian wetlands. A National Riparian Program which collects and synthesizes information, which continuously redefines best technology currently available for riparian management and protection, and which delivers information, technology, and management guidelines to local, state, and federal field offices, is the only way we will address this national problem. Which agency serves as a home for a National Riparian Program is less important than full coordination and participation by all agencies within the hierarchy described by Jon Kusler earlier this morning. This is precisely the type of initiative President Carter seeks in order to gain greater efficiency, reduced cost, and increased protection of natural resources through increased cooperation and a more clear definition of issues.

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[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Piparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

[2]Director, Graduate Program in Ecology, University of Tennessee, Knoxville, TN 37916.

A proposal for a National Riparian Program has been submitted and reviewed within the Department of the Interior. It will not be implemented, it will not be funded, without strong support throughout that Department, especially from its regional offices, state governments, and conservation and environmental organizations. It will not, and should not, be implemented without strong endorsement, full coordination, and active participation by other agencies. Many of those whose support is required are participants in this symposium.

I urge those in positions of responsibility to support a proposal for a National Riparian Program, to go beyond present scattered and diverse efforts to manage and protect riparian wetlands. I am confident that those of us in the nation's universities will continue to provide the necessary information base, those in local and state government will continue their support and will continue to identify management needs, environmental and conservation organizations will continue to provide motivation, _if_ appropriate agency administrators will take action to develop a coordinated interagency program to improve management and protection of riparian wetlands. The need for improved management of riparian wetlands is not unlike an earlier need for coastal zone management.

Throughout the symposium I have paid special attention to descriptions and examples of the characteristics of riparian wetlands. These are the functional and structural properties which form the scientific basis for management and policy decisions. These fundamental properties are products of the universal laws, operating within the riparian environment, which Assistant Secretary Herbst identified as the appropriate basis for resource management systems. If, as he recommends, we are to develop management systems which fit the systems to be managed, an understanding of these characteristics is essential.

This symposium and its participants have addressed this need directly. More clearly than before, RIPARIAN WETLANDS ARE...lowland terrestrial ecotones which derive their high water tables and alluvial soils from drainage and erosion of adjacent uplands on the one side, or from periodic flooding from aquatic ecosystems on the other. Extensive interactions with adjacent terrestrial and aquatic ecosystems include their moderation of water quantity and quality, mineral conservation, gas exchange, soil stabilization, and their role as a wildlife habitat of unusually high value. Riparian wetlands, as true ecotones, share certain characteristics of adjacent upland and aquatic ecosystems, yet express their individuality through species composition, ecosystem structure, high productivity, and high species diversity. High kinetic energy derived from the hydrologic cycle may be responsible for the most unique characteristics of riparian wetlands. They are relatively open systems in terms of their tole in energy flow, mineral and hydrologic cycles, and use by fish, wildlife and man. They are a natural buffer between aquatic and terrestrial ecosystems. They quite naturally mitigate impacts of natural or anthropogenic activities occurring in either adjacent ecosystem. Riparian wetlands occur throughout the United States, most common examples being streambank communities in the west and bottomland hardwood or floodplain forests in the east.

I concur with Assistant Secretary Herbst's earlier statements that:

(1) We must develop management systems which fit the systems to be managed.

(2) We must design and implement technology which is compatible with natural laws (and ecological processes), rather than those which fight the forces of entropy of gravity as manifested in flooding, tides or biological productivity.

(3) we must gain public acceptance and participation in improved management of riparian wetlands through environmental education.

The latter is essential to achieve participation of all relevant organizations as called for by Jon Kusler earlier in this symposium.

In conclusion, most of those in my profession, that of an ecologist in the security and sanctity of a university, would be skeptical of our chance for success in achieving the major goals identified:

(1) improved riparian management and protection,

(2) policy decisions, including implementation of a National Riparian Program,

(3) environmental education necessary to improve public awareness and participation.

However, I am enthusiastically confident that these goals will be achieved, if not in FY 80, at least by FY 81. I base my confidence upon experiences of the past year during which I became increasingly familiar with many of the policies and people in our nation's natural resource agencies. To a great extent I gained confidence from association with my colleague in organizing this symposium, Dr. Roy. Johnson.

Poster Session

The Warm Springs Riparian Dilemma[1]

Richard L. Bailey[2]

Abstract.--Corps of Engineer policies regarding the public interest in riparian areas downstream from major water resource projects are poorly defined, as exemplified by this case study of the Warm Springs Dam in California. Corps authority and responsibility downstream is uncertain, despite extensive changes in the area that will be caused there by operation of the dam. The concept of a private land use trust to protect riparian habitat of public value while preserving private property rights emerged as a potentially viable compromise to proposals for fee purchase of riparian lands.

INTRODUCTION

The purpose of this paper is to stimulate discussion on riparian issues which are of national significance, by presenting a case history of an exemplary project developed by the Corps of Engineers. The riparian resource problems described in this paper are manifested whenever a large water resource project is contemplated, and will continue to challenge resource managers with increasing frequency in the future. In this case history, the problems are yet to be resolved despite considerable effort by the agencies involved. The situation indicates a lack of strong, uniform guidelines in the area of riparian zone management. The development of such guideleines is an appropriate topic for resolution by this conference.

The Army Corps of Engineers, San Francisco District, is currently constructing the Warm Springs Dam on Dry Creek in Sonoma County, California. When operational in 1984, the waters released from the dam will change Dry Creek from a seasonal stream into a perennial stream with substantial summer flow. The Corps is also constructing a fish hatchery at the site, and thousands of trout and salmon will be released into Dry Creek. These changes, creation of a potential recreation stream and a new fishery, will have many important secondary effects. Such effects commonly occur in similar situations throughout the country and are summarized in Table 1.

At the present time, the Corps of Engineers, the U. S. Fish and Wildlife Service and the California Resources Agency are still struggling with the policy questions relating to these effects. In short, they are trying to protect the riparian resource, maintain private property rights, satisfy Corps responsibility to mitigate for riparian habitat flooded by the dam and provide for the public interest in the newly created fishery and recreational resources.

THE RIPARIAN SETTING

The downstream area to be impacted by the Warm Springs Dam includes 14 miles of Dry Creek and its associated riparian habitat. The streambed is gravel lined and varies from about 50 to several hundred feet wide. In several places the banks have been severely eroded and landowners have deposited automobile bodies or rock rip-rap along the stream to protect their cropland. Riparian vegetation on the banks includes willow, alder, cottonwood, and numerous other species which provide erosion protection and significant wildlife habitat. This riparian zone forms a buffer between the water (which is used by cities downstream) and the adjacent irrigated vineyards and orchards, which completely dominate present land use in the valley. These croplands are highly valuable, having been called "the greatest grape growing area in the world" by farmers seeking to prevent public acquisition of the riparian zone. Several hundred property owners, organized into a valleywide landowners association, own portions of the streambed and adjacent riparian habitat. Three bridges cross the stream between the dam and its mouth at the Russian River.

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[1]Paper presented at the National Riparian Ecosystems Symposium, Calloway Gardens, Georgia, December 11-13, 1978.

[2]Fish and Wildlife Biologist, U. S. Fish and Wildlife Service, Atlanta, Georgia.

Table 1.--Potential effects of dam construction on downstream habitat.

Project Component	Mechanism	Effect
Reservoir - Flooding of habitat	Elimination of existing riparian zone.	Requirement to mitigate for lost habitat.
Dam	Controlled release schedule; increase in summer flows.	Recreationists use stream for canoeing; trespass problems develop.
Fish Hatchery	Smolts released in stream; adult salmon return to spawn. Fishermen seek access to stream.	New fishery resource created; landowner-fishermen conflicts occur.
Reservoir - Flood control	Elimination of severe winter flooding and erosion.	Landowners plant crops closer to stream; destroy riparian habitat.
Reservoir - Silt settlement	Clear water release; increased erosive power.	Stream degradation; increase in bank erosion; Rip-rap installed.

MITIGATION PROPOSALS

In commenting on the environmental impact statement for the dam and in later correspondence, the U. S. Fish and Wildlife Service (Federal) and the California Resources Agency (State) requested that the Corps study methods of providing fishermen access and riparian protection downstream from the dam as mitigation for areas to be flooded. Because of protracted litigation and court injunctions which delayed construction of the dam, this issue was not addressed in the supplement to the impact statement, or in other official Corps publications. But when renewed construction of the dam became imminent, the State required that several conditions be met before agreeing to support continuation of the project. One of these conditions was a commitment to consider providing for riparian protection and public access downstream from the dam. The U. S. Fish and Wildlife Service made a similar request and in early 1978, the Corps agreed to study downstream alternatives as part of its master plan for the project.

A subsequent state-federal mitigation report to the Corps outlined detailed proposals for a downstream program including parking lots at bridge crossings, fee acquisition of the streambed and fee acquisition or an easement on the riparian zone as defined by the existing native vegetation. The proposal would provide for public canoeing and fishing, and would prevent landowners from destroying riparian vegetation by moving their farming operations closer to the channel.

THE PUBLIC PARTICIPATION PROGRAM

In conjunction with the development of a master plan for the project, the Corps hired a consulting team to conduct a public participation program. The goal of the program was to determine what the public wanted or did not want with respect to facility development and land use. The consulting team promised two-way communication, wherein the public would express their opinions and at the same time learn about opposing viewpoints and the Corps responsibility for mitigation as requested by the U. S. Fish and Wildlife Service and the Resource Agency.

Hearings were held locally in towns several hours from major population centers. One special workshop (held on Saturday so that local citizens could attend) focused on the downstream issues of riparian protection and public access to the stream. The workshop provided a focus of attention and a platform for expression of local viewpoints.

Despite efforts to involve a wider segment of people in the program, the input received was not a broad sample of the general public who might be expected to use the project facilities. Because of this, only a few individuals and the State Department of Fish and Game made any vocal efforts to support public access or protection of the riparian zone. The Department of Fish and Game declared that trespassing by fishermen would be much worse if no public use areas were established. The U. S. Fish and Wildlife Service issued a report proposing riparian protection and public access, but did not verbally defend it. Corps employees were not encouraged to speak out at the hearings and the Corps role was stressed to be one of balancing factors and determining the true public interest. As a consequence, if decision makers decide to base their choice only on the results of the public participation program, there will be no public access to the riparian zone downstream from the dam.

PUBLIC OUTCRY

Upon hearing vague outlines of the public acquisition proposals, landowners in the valley had quickly organized into a cohesive and vocal group. At meetings called by the Dry Creek Valley Association, representatives of the Corps, Federal and State agencies were subjected to jeers, catcalls, and demands that public agencies be reponsive to the taxpayers (as represented by their organization). Opposition to Corps involvement downstream centered on the proposed public access, and almost totally ignored provisions for potential riparian protection. The farmers declared that recreation in the streambed was totally incompatible with farming in the valley and that their equipment and lands would be subject to uncontrolled vandalism and trespass. Proposals were made to move the hatchery elsewhere or to reduce the number of fish produced at the hatchery so that the stream would not attract fishermen. When Corps surveyors attempted to secure legal rights of entry to the streambank for erosion control studies, most landowners refused to cooperate.

During the ensuing public hearings on the master plan, the County Commission passed a resolution against downstream acquisition, and several newspapers printed editorials condemning the downstream proposals. In the wake of Proposition 13, taxpayers complained that the program was a waste of money. The Corps also received a letter from a congressional representative who critcized the state and federal proposals. Hearings were well attended and vocal. Even a sport fishing group rejected the idea of creating a new fishing resource since the fish would be artifically produced, not native, and too easy to catch. Petitions were circulated and numerous letters complaining of governmental indifference to the people's wishes were received.

Anti-public access sentiment was universal, but on the issue of riparian protection, the landowners expressed cautious interest. Many could see the benefits of preserving riparian vegetation as a means of erosion control, but were suspicious of any governmental program. A position paper prepared by the landowner's association left the door open for the establishment of some form of riparian preservation under the control of the landowners.

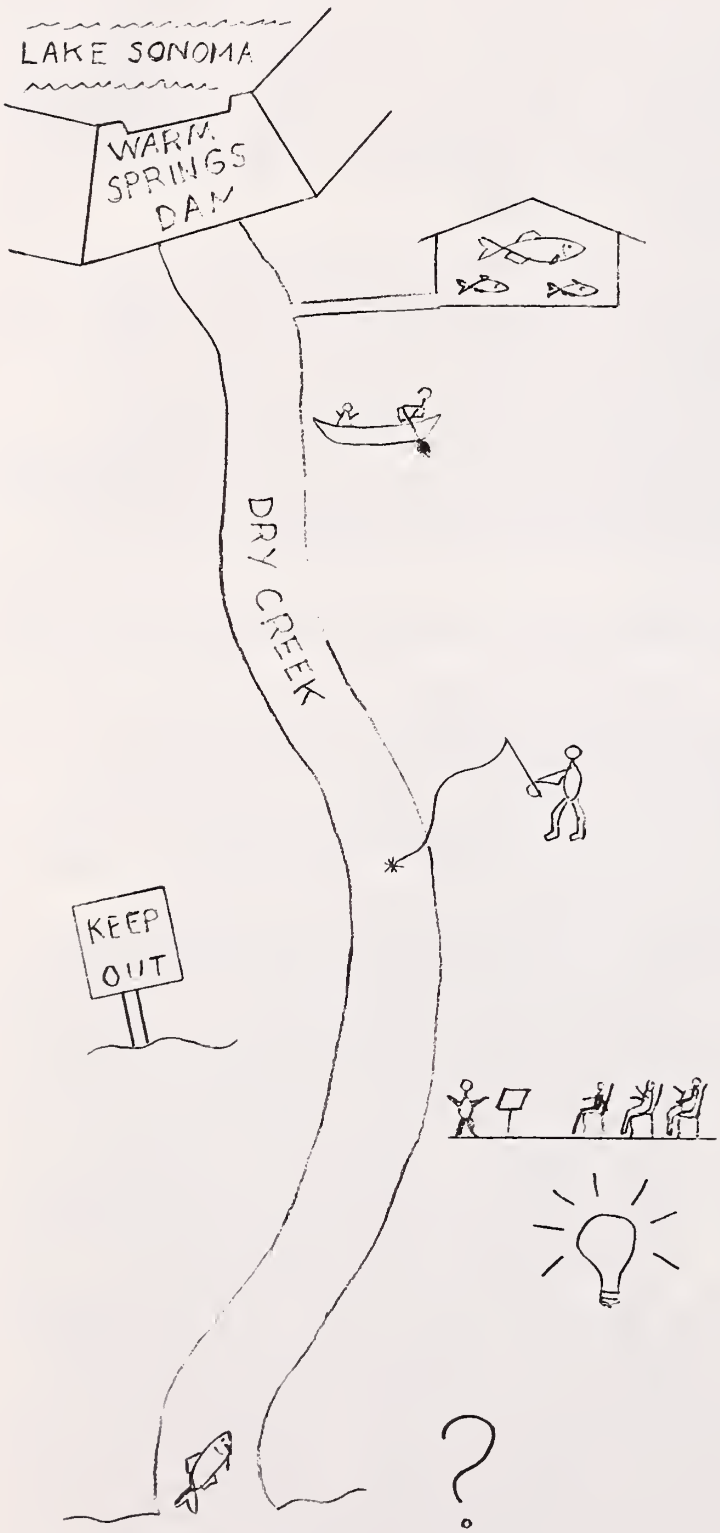
EVOLUTION OF THE PUBLIC TRUST IDEA

Landowner opposition to protection of the existing riparian habitat was based on the proposal for fee acquisition and on mistrust of government ownership. When this became clear, a compromise alternative began to emerge. The idea of a riparian easement (not fee acquisition) to protect existing vegetation between the streambed and the farmland began to gain acceptance. Such an easement might be purchased by the Corps, but the landowners would still hold title to the property. Costs for such an easement, which would not allow public access, were estimated to be one-third the cost of fee acquisition. At this point, the concept of a land trust emerged. A land trust is an agreement between property owners to place restrictions on the use of or future sale of the land, or on other rights associated with ownership or use. It is flexible in scale and scope, and can be legally binding. A trust, not the Corps, could be the agency that obtained and controlled the easement. Such a mechanism for protection of certain public values while simultaneously retaining private control of land has been in use for many years, but until the controversy erupted, the idea was never considered by the Corps or the Federal/State agencies. The land trust could be administered by one of several groups: a property owner association, or the existing Sonoma County Land Trust. It was learned that the National organization "Trust for Public Land" (TPL), could provide technical assistance in establishing a land trust.

WARM SPRINGS DAM

SONOMA COUNTY, CALIFORNIA

Does creating a public resource imply responsibility for riparian protection?



Construct dam on seasonal stream.

Build a fish hatchery.

Create a perennial stream suitable for recreation.

Salmon and stream create new potential resource opportunities.

State Fish and Game Commission and U. S. Fish and Wildlife Service propose public access and riparian protection.

Landowners and local government revolt, refuse cooperation.

Corps holds public hearings.

Compromise proposed - No access - but obtain a riparian easement/land trust.

Corps of Engineers decides that Congressional approval is needed. Program is left unresolved.

Figure 1.--Diagram of the Warm Springs Dam Riparian dilemma.

Protection of the riparian habitat with an easement held by a land trust appealed to both the Corps and property owners. Such action would save the Corps thousands of dollars, provide significant tax breaks for property owners, and alleviate landowner fears of governmental take-over, subsequent loss of water rights and trespass problems. While the Fish and Wildlife Service took no formal position on the trust idea, the California Department of Fish and Game was cautious, declaring that such a mechanism would have to be legally binding before they could give their support. As the public participation process entered its final stages, interest was high in establishing a riparian protection easement held by a land trust.

THE CURRENT SITUATION

During a review of the master plan which was to determine the downstream program, the Corps reversed itself. It was decided that any Corps involvement downstream other than erosion control would require a "post-authorization change," which means approval by Congress. Such a process could easily require one to two years, or more. At this point, the entire downstream issue was removed from the master plan, and the downstream riparian questions were left unresolved.

Such action satisfied the property owners, but did not relieve the Corps responsibility to mitigate for riparian habitat to be flooded by the dam. It also did not satisfy the state request to provide public access to the riparian zone for fishermen. The land trust idea, however, would probably not require Congressional approval, and could conceivably satisfy the state-federal requests. At present, Corps officials and landowners are holding occasional meetings on the subject, but with the fear of Corps condemnation removed, progress on the part of the property owners is slow. Efforts are proceeding to secure a post-authorization change to provide the authority for purchase of riparian easements. Figure 1 provides a summary of the events that have led to the current situation.

CONCLUSIONS

The primary conclusion of this case study is that the land trust concept should receive increasing attention as a mechanism for protection of riparian habitat. Such trusts operate by the voluntary limitation of private property rights in areas where there is a substantial public interest in land or resources. They may or may not include public agencies and/or professional organizations established to facilitate such action. Land trusts can guarantee specific private property rights while simultaneously preserving public values and allowing some public use of the land. These characteristics make land trusts particularly appropriate in riparian areas where shoreline vegetation should be protected, or where limited day-use recreation can be established in conjunction with water resource projects.

The second major conclusion is that the responsibilities of the Army Corps of Engineers and other major water resource agencies for areas downstream of their projects should be better defined. Despite the frequency of involvement in riparian issues below dams, Corps policy on anything but erosion control is nebulous. Although the importance of wetland, flood plain, salt marsh, and other types of riparian habitat has been stated in national policy, and a national wetlands inventory is being conducted, the mechanisms for protection and use of such areas need additional elaboration.

Coastal Georgia as a Part of the National Wetland Inventory[1]

Frederick P. Pariani & John R. Bozeman[2]

Abstract.--Georgia-National Wetland Inventory. Approximately 4,600 square miles of coastal wetlands in Georgia were classified and mapped in cooperation with the U.S. Fish and Wildlife Service - National Wetland Inventory Program. Products of this effort include 1:100,000 general class maps and 1:24,000 detailed systems maps. Key words: Marine, Estuarine, Riverine, Lacustrine, and Palustrine wetlands.

The State of Georgia, in contract with the United States Fish and Wildlife Service, has successfully mapped the wetlands throughout 4,600 square miles of its coastline. The project area included the Brunswick 1:250,000 U.S.G.S. map, the northern half of the Jacksonville 1:250,000, and the southern half of the Savannah 1:250,000 map. Using the Cowardin (1977), classification system of the National Wetland Inventory and recent color infrared stereo-paired photography as a vehicle, the Georgia Department of Natural Resources has delineated individual wetlands according to their type, size, and location.

The classification scheme is composed of five (5) major systems which are further defined by an hierarchical structure of subsystem, class, and subclass. Hydric conditions in each individual wetland type are noted by using water regime modifiers. Additional modifiers are also used to further clarify each wetland type.

The five major systems include: Marine, Estuarine, Riverine, Lacustrine, and Palustrine. The Altamaha River is used to emphasize the Riverine system through topographical maps portraying wetland classifications. These maps are also exhibited as examples of the National Wetland Inventory's operational products. Color photographs elucidating various aspects and features of the Riverine system in particular and the classification system in general are keyed to areas on the base maps. A slide presentation with text outlines this entire project and describes the classification system as it applies to the coast of Georgia.

[1]Paper presented at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

[2]F. P. Pariani, Research Consultant and J. R. Bozeman, Project Leader and Assistant Director, Marshlands Protection, Coastal Resources Division, GA Department of Natural Resources, Brunswick, GA.

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Avian Population Responses to Salt Cedar Along the Lower Colorado River[1]

Dan R. Cohan, Bertin W. Anderson and Robert D. Ohmart[2]

Abstract.--Avian population responses to salt cedar were studied seasonally for three years along the lower Colorado River. Bird densities and diversities were examined in salt cedar and three additional types of riparian vegetation, all of similar horizontal and vertical configuration. Avian species were found to react to these plant community types seasonally in one of eight major ways. Three reaction types included species which showed a preference for or at least appeared not to avoid salt cedar, but the species involved represented a minority of the total species in the four vegetative types. Species which preferred or appeared not to avoid salt cedar were primarily ground feeders, granivores, or species which fed largely in other habitat types (e.g., agriculture). A disporportionate number of the species tolerating salt cedar belonged to Old World genera. Insectivores in general and frugivores in particular seemed to show greatest intolerance of salt cedar. Significantly fewer insectivores used salt cedar than would be predicted on the basis of insect biomass. Avoidance of salt cedar by insectivores may be related to the sticky exudate which may damage the plumage. Frugivores were absent from salt cedar because of the near total absence of available fruits and berries.

INTRODUCTION

The exotic salt cedar (Tamarix chinensis) was introduced into North America in the early 1800's for ornamental purposes (Horton 1977). By its successful competition with indigenous vegetation, salt cedar has been proven to be a very aggressive species. This is particularly true in areas which formerly flooded annually but which now remain dry as a result of dams along the Colorado River. The absence of flooding allows litter accumulation; subsequent fire kills or retards indigenous vegetation but not salt cedar (Ohmart, et al. 1977). Since the early 1900's salt cedar has become the dominant plant species and has replaced natural stands of cottonwood (Populus fremontii), willow (Salix gooddingii), screwbean mesquite (Prosopis pubescens), and honey mesquite (Prosopis juliflora) (Ohmart, et al. 1977).

We have been studying the avifauna of salt cedar and other riparian communities along the lower 443 km of the Colorado River since 1973. The study area encompasess some 4,400 ha of riparian vegetation and includes all of the major plant community types found along the lower river.

The value of salt cedar for birds has been discussed in a preliminary report (Anderson, et al. 1977a). They reported that in general salt cedar did not seem to attract as many species and in as great densities as vegetation indigenous to the Colorado River Valley. It was not their intent to answer questions relative to which species avoid salt cedar, which ones seemed to prefer it, nor to deal with seasonal responses of birds to salt cedar. They made only cursory comments about why various species may be avoiding salt cedar. This report is directed toward these particular points.

[1]Paper presented at the National Symposium on Stragegies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Pine Mountain, Georgia, December 11-13, 1978.

[2]Respectively, Field Biologist, Faculty Research Associate, and Associate Professor of Zoology, Arizona State University, Department of Zoology and Center for Environmental Studies, Tempe, Arizona 85281.

METHODS

Six riparian community types were recognized in the valley using dominant vegetation as the criterion. Based on vertical profiles, these six dominant community types were subdivided into as many as six structural types (I-VI), each differing from the other by vertical structure, dominant vegetation, or both. For plant and animal sampling purposes we had at least four areas of 20 to 40 ha represented in each community-structural type. For details see Anderson et al (1977b).

Horizontal foliage diversity (HFD) is a measure of patchiness in a stand of vegetation. We calculated HFD for all major community types by establishing lines or transects 800 to 1,600 m long through the vegetation. Intervals of 150 m were marked along each line. Foliage volume measurements using the board technique (MacArthur and MacArthur 1961) were taken at heights of 0.2, 0.6, 1.5, 3.0, 4.5, 6.0, 7.5, 9.0, and every 1.5 m thereafter. Distance readings were converted to relative foliage volume and the mean of 2 or 3 points at each height was used to represent the vegetation profile in each 150 m section on each side of the line. A 1,500 m line would have a total of 20 sections (10 on each side). HFD for a given layer was the variance of the means for the 20 sections along the line (Anderson and Ohmart 1978).

Foliage height diversity (FHD), a measure of the vertical foliage diversity in a community, was calculated from $-\Sigma p_i \ln p_i$ where p_i represents the proportion of volume at the ith level using the same measurements as for HFD (Table 1).

The number of trees of each species in each area was determined by counting all trees within 15 m of the transect in each 150 m interval. The density of each tree species was expressed as the number per 0.2 ha.

The modified Emlen transect technique was used in censusing birds (Emlen 1971, 1977, Anderson, _et al_. 1977b). Each transect was censused 3 times per month. Bird densities in this report represent the average of 3 censuses per month for the 3-year period 1975-77 and were expressed as the number per 40 ha. Those species which had an average density less than 0.5 per 40 ha were excluded from the total.

Seasonal densities were derived by averaging the mean monthly densities for each season. Seasons included winter (December, January, February); spring (March, April); summer (May, June, July); late summer (August, September); and fall (October, November).

Insect biomass in each community was determined by weighing insects captured with 4,000 sweeps with an insect net on a transect in each community each month.

In order to facilitate discussion and to conserve on space, our discussion in this report draws on data collected from salt cedar, honey mesquite, willow, and mixed salt cedar-honey mesquite communities of vertical structural type IV only. Inclusion of other structural types would not alter any conclusions herein. It should also be emphasized that type IV is the most common vegetative configuration, constituting some 60 to 70 percent of the vegetation in the valley (Anderson and Ohmart 1976).

Table 1.--Transect information and vegetation analyses for four community types found along the lower Colorado River. (Key: SC represents salt cedar; W, willow; SH, stands of mixed salt cedar and honey mesquite; HM, honey mesquite; FHD, foliage height diversity; HFD, horizontal foliage diversity.

	Number of Trees Per 0.2 Ha						Length of Transects (m)		Area (Ha)	
Community	SC	W	HM	Total	FHD	HFD	Total	Mean	Total	Mean Per Transect
SC	182	0	1	183	0.974	0.086	3,344	836	84	21
W	98	32	12	142	1.060	0.106	6,384	912	161	23
SH	34	0	16	50	0.892	0.074	3,800	950	96	24
HM	0	0	29	29	1.023	0.087	13,376	1,216	337	31

The average length (1.0 km) of the 26 transects in the type IV communities represented an area of about 25 ha (Table 1). Although the area represented by each community was quite different, it probably had little influence on the results. This conclusion is based on the findings (Anderson and Ohmart 1977) that avian density and diversity did not change much with additional transects after the total had reached 2500 to 3000 m in any particular vegetation type.

The vegetative characteristics were similar among the structural types studied, but willow somewhat exceeded the rest in HFD and FHD. This difference was mainly attributable to the presence of more vegetation above 7.5 m in willow stands. Areas classified as willow had a rather dense understory of salt cedar. In these areas, while salt cedar trees outnumbered willows, the latter were taller and occupied more area per tree on the average. Stands of mixed honey mesquite and salt cedar were recognized as distinct community types. Stands of honey mesquite with virtually no other kinds of trees were abundant and were one of the most distinct community types present. Stands termed salt cedar had virtually no other tree species present.

In structural type IV vegetation, 40 to 55 percent of the foliage volume was between 1.5 and 4.5 m. Between 10 and 20 percent was greater than 4.5 m, but almost none was greater than 8 m. Vegetation less than 1.5 m constituted between 30 and 40 percent of the total volume.

Birds were found to react to salt cedar in eight different ways. Species which reacted similarly were placed in a species group. Each of these groups, assigned a letter A-H, was represented diagrammatically in figure 1. Group A was represented by species with greatest densities where salt cedar was the only tree present; group B species were those in which salt cedar was supplemented by willow; group C species were in areas with salt cedar supplemented by willow and in areas where there was no salt cedar; group D species occupied areas with salt cedar supplemented by honey mesquite; group E species were in areas with no salt cedar; group F species were found in equal densities in all areas; group G species were in pure stands of salt cedar and pure stands of honey mesquite; group H species were in areas where salt cedar was supplemented by willow and in areas where salt cedar was supplemented by honey mesquite.

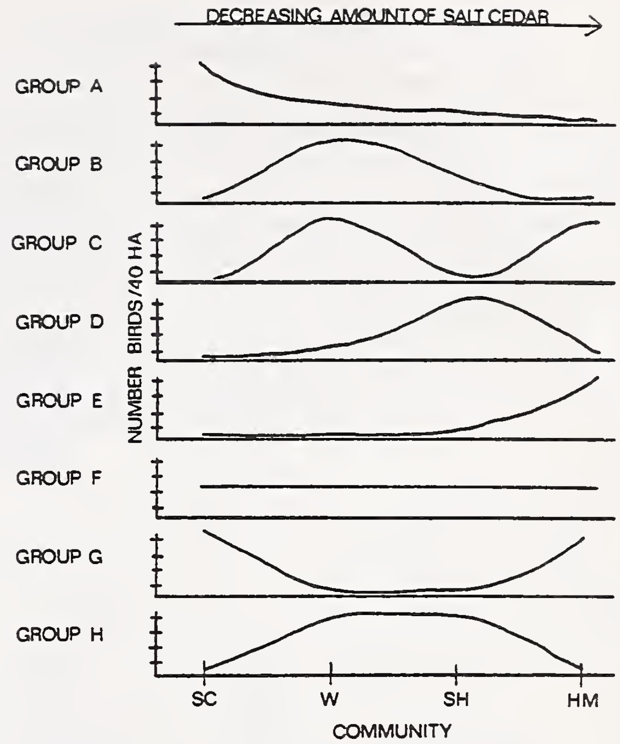

Figure 1.--Diagrammatic representation of the ways birds reacted to salt cedar.

RESULTS

Densities by Community

Bird densities were greatest in willow and honey mesquite, moderate in salt cedar-honey mesquite mixes, and smallest in salt cedar in summer (fig. 2). In willow and honey mesquite avian densities remained relatively high in winter, but were relatively low in pure stands of salt cedar and in stands of mixed salt cedar and honey mesquite. Bird densities during spring, late summer and fall tended to be similar for each vegetative type relative to the other vegetative types, with salt cedar having the smallest population.

Seasonal Variation in Group A

Those species with maximum densities in stands of pure salt cedar (group A) reached greatest total densities during summer (fig. 3). Differences in densities between summer and late summer were significant (0.01>p>0.005). No birds occurred in this group in winter, spring or fall. There were 5 and 3 species present in late summer and summer, respectively (Table 2, Appendix I).

Table 2.--Number of bird species, percent of total number of species, number of granivorous and insectivorous species and species of uncertain food habits occurring in various groups (see text for description of groups) during the five seasons. Values for each season represent the average for the season for three years (1975-77).

Groups Present and Season	Number of Species	Percent of Total Species	Number of Insectivorous Species	Number of Granivorous Species	Uncertain
Winter					
B	22	53.7	16	4	0
D	3	7.3	2	1	2
E	14	34.2	3	11	0
F	1	2.5	1	0	0
H	1	2.5	1	0	0
Total Species	41		23	16	2
Percent of Total		100.2[1]	56.1	39.0	4.9
Spring					
B	18	40.0	11	7	0
C	8	17.8	8	0	0
D	5	11.1	2	3	0
E	12	26.6	2	10	0
F	2	4.4	1	1	0
Total Species	45		24	21	0
Percent of Total		99.9[1]	51.0	44.6	0
Summer					
A	3	7.3	0	3	0
B	19	46.3	14	4	1
C	6	14.6	5	1	0
E	6	14.6	5	1	0
F	4	9.7	4	0	0
G	3	7.3	1	2	0
Total Species	41		28	11	1
Percent of Total		99.8[1]	68.3	26.8	2.4
Late Summer					
A	5	13.2	2	3	0
B	18	47.4	13	5	0
E	7	18.4	5	2	0
F	5	13.2	4	1	0
H	3	7.9	1	2	0
Total Species	38		25	13	0
Percent of Total		100.1[1]	65.8	34.2	0
Fall					
B	8	25.0	6	2	0
C	6	18.8	5	1	0
D	6	18.8	4	2	0
E	8	25.0	0	8	0
F	4	12.5	3	1	0
Total Species	32		18	14	0
Percent of Total		100.1[1]	65.2	43.8	0

[1]Totals not equaling 100 percent are due to rounding off.

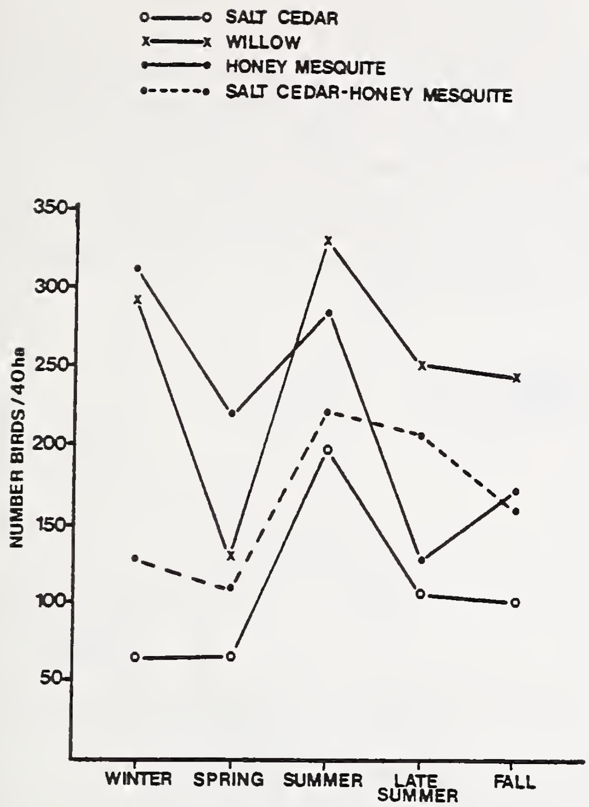

Figure 2.--Average avian densities for various seasons (1975-77) in communities along the lower Colorado River.

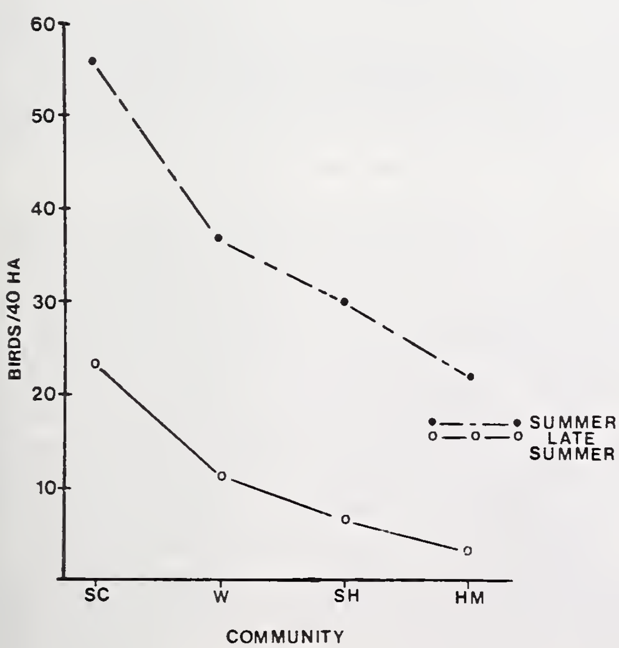

Figure 3.--Birds with greatest densities in salt cedar communities (group A). Abbreviations as in Table 1.

Seasonal Variation in Group B

Total densities of birds tolerating salt cedar when it was supplemented by willow (fig. 4) reached peak numbers during winter, were smallest during spring, and were intermediate at other seasons. Total densities did not differ (p>0.05) in spring and late summer. There were 22 species present in this group in winter, 18 in spring and late summer, 19 in summer, and 8 in fall (Table 2, Appendix I). This group included over 40 percent of the total species present in all but one season (fall).

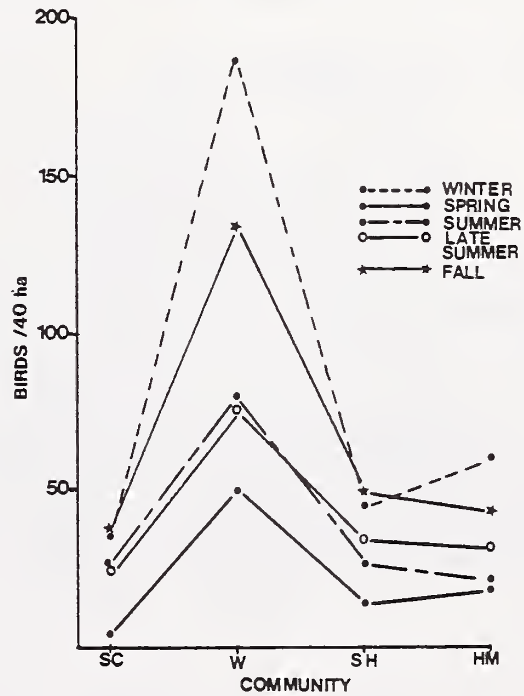

Figure 4.--Birds with greatest densities in willow communities (group B). Abbreviations as in Table 1.

Seasonal Variation in Group C

Species in group C tolerated salt cedar when it was supplemented by willow but reached peaks about as great in honey mesquite, where salt cedar was absent. Densities in this group were greatest in summer, were much smaller in spring and fall, and the group was not represented in late summer or winter (fig. 5). A total of 8 species occurred in this group in spring and 6 in summer and fall (Table 2, Appendix I).

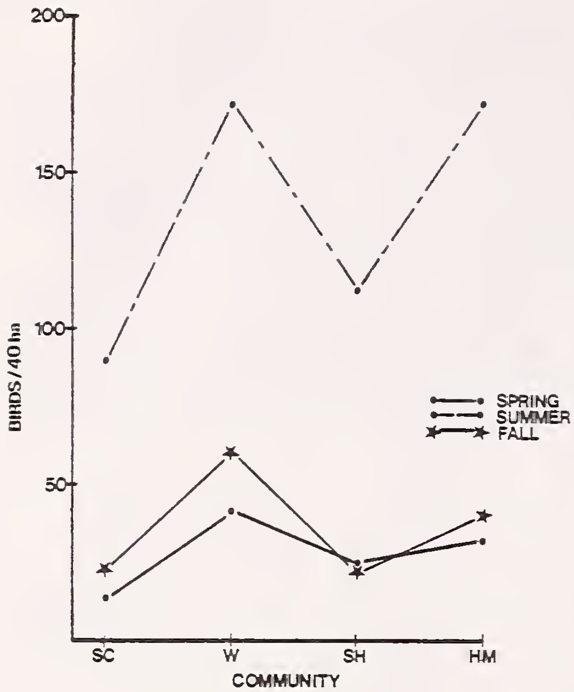

Figure 5.--Birds with greatest densities in willow and honey mesquite communities (group C). Abbreviations as in Table 1.

Seasonal Variation in Group D

Those species tolerant of salt cedar when it was supplemented with honey mesquite reached maximum densities in fall (fig. 6). Densities during spring and winter were smaller than during fall and the group was not represented in summer or late summer. Six species comprised this group in fall, 3 in winter and 5 in spring (Table 2, Appendix I).

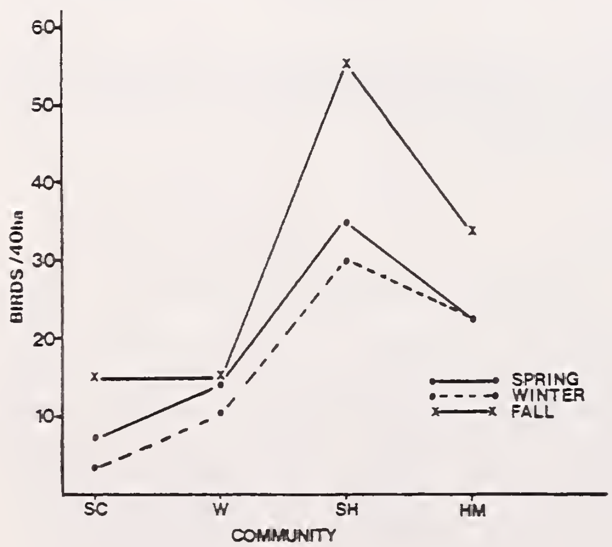

Figure 6.--Birds with greatest densities in salt cedar-honey mesquite communities (group D). Abbreviations as in Table 1.

Seasonal Variation in Group E

This species group reached maximum densities in honey mesquite (where salt cedar was entirely absent) during winter and was most poorly represented in summer (fig. 7). The group was represented in winter by 14 species, in spring by 12, in summer by 6, in late summer by 7, and in fall by 8 species (Table 2, Appendix I).

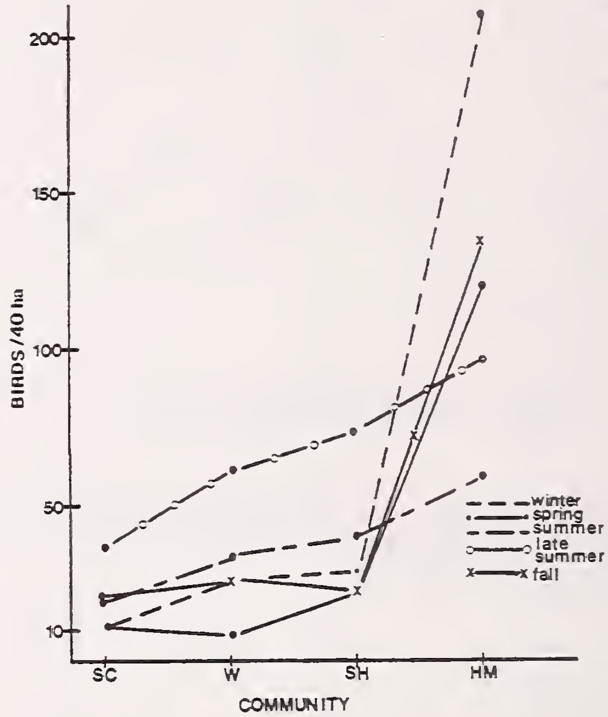

Figure 7.--Birds with greatest densities in honey mesquite communities (group E). Abbreviations as in Table 1.

Seasonal variation in Group F

Birds which did not deviate ($p>0.05$) from an even distribution among the 4 vegetative types investigated reached maximum densities in spring, late summer and fall and were nearly absent in winter (fig. 8). The birds in this group reached somewhat greater densities in spring, and a somewhat greater density in salt cedar in fall, but numbers were too small to detect a significant trend. The group was characterized by having few species. The peak number of species (5) was reached in late summer; there were 4 species in summer and fall, 2 species in spring, and one in winter (Table 2, Appendix I).

Seasonal Variation in Group G

Birds were present in group G only in summer (fig. 8) when there were 3 species present (Table 2, Appendix I).

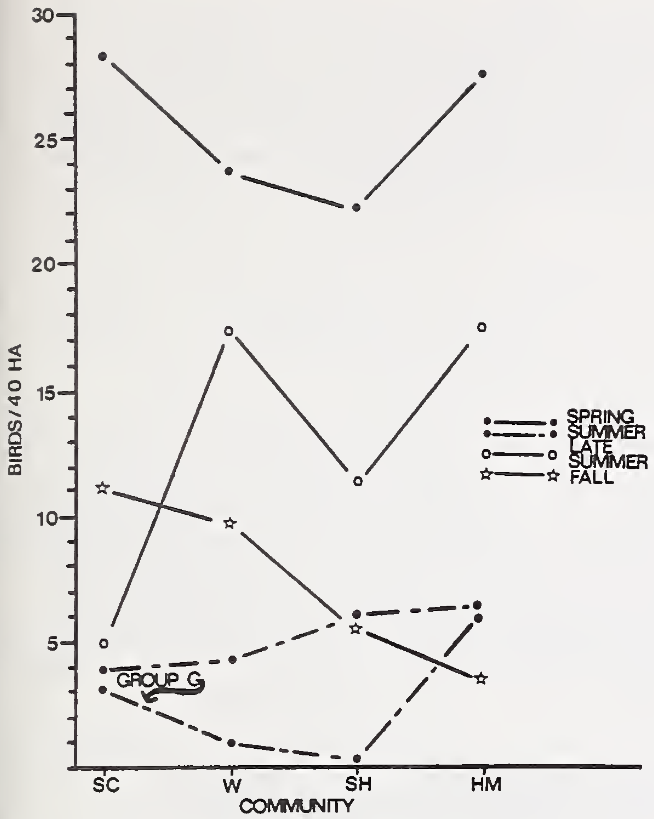

Figure 8.--Birds with densities occurring equally in all communities (group F) or with greatest densities in salt cedar and honey mesquite communities (group G). Abbreviations as in Table 1.

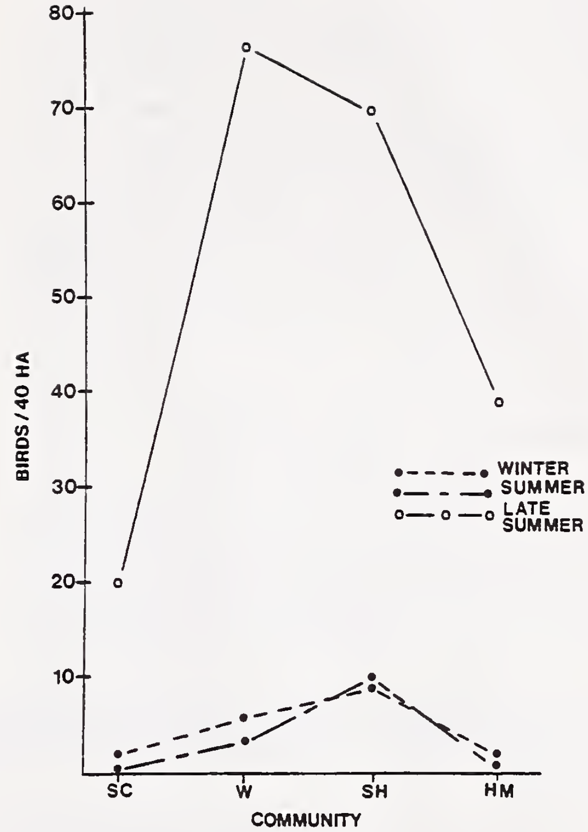

Figure 9.--Birds with greatest densities in willow and salt cedar-honey mesquite communities (group H). Abbreviations as in Table 1.

Seasonal Variation in Group H

Densities of birds showing preference for willow and mixed salt cedar-honey mesquite communities were most abundant in late summer and were nearly absent at other seasons (fig. 9). Three species comprised the group in late summer and one in winter (Table 2, Appendix I).

Overall Species Response to Salt Cedar

In winter and spring only a single species out of 41 and 45 species, respectively, showed tolerance to salt cedar (Table 2). This was an insectivorous species (Gila Woodpecker, Melanerpes uropygialis) in winter and a ground feeding granivorous species (Mourning Dove, Zenaida macroura) in spring. In summer, 10 of 41 species showed tolerance to salt cedar. All of them were primary consumers and included the Mockingbird (Mimus polyglottos), House Sparrow (Passer domesticus), White-crowned Sparrow (Zonotrichia leucophrys), White-winged Dove (Zenaida asiatica), and Ground Dove (Columbina passerina). The last 4 of these are ground feeders which feed extensively in agricultural areas or are largely absent in summer (White-crowned Sparrow). Among the 5 insectivores, the Cliff Swallow (Petrochelidon pyrrhonota) feeds aerially over salt cedar, and the Roadrunner (Geococcyx californianus) is a ground feeder. Only the Bell Vireo (Vireo bellii), Blue Grosbeak (Guiraca caerulea), and Black-tailed Gnatcatcher (Polioptila melanura) feed in the vegetation.

In late summer 10 of 38 species showed extensive tolerance of salt cedar. Among them, 4 (White-crowned Sparrow, Brown-headed Cowbird, Molothrus ater, Lincoln Sparrow, Melospiza lincolnii, and Ground Dove) feed extensively in agricultural areas or marshes (Lincoln Sparrow). Among the 5 insectivores were 4 permanent residents, the Gila Woodpecker, Ladder-backed Woodpecker (Picoides scalaris), Crissal Thrasher (Toxostoma dorsale), and Loggerhead Shrike (Lanius ludovicianus), and one winter visitor, the Ruby-crowned Kinglet (Regulus calendula).

In fall 4 species showed as much or more tolerance to salt cedar as other riparian vegetation. These were the Chipping Sparrow (Spizella passerina), Blue-gray Gnatcatcher (Polioptila caerulea), Starling (Sturnus vulgaris), and Orange-crowned Warbler (Vermivora celata). The Chipping Sparrow and Starling feed primarily in agricultural areas; the gnatcatcher and warbler are insectivorous.

In summary, among the 19 species (of 65 total species) which showed as much tolerance to salt cedar as other riparian vegetation (groups A, F and G), only 2 species displayed this tolerance during more than one season (White-crowned Sparrow and Ground Dove). Among the 19 species, 8 fed largely outside of riparian vegetation. Eleven species were largely riparian and among them only one, the Gila Woodpecker, tolerated salt cedar as much as the other vegetation types during more than one of the five seasons.

Numerically Dominant Birds in Salt Cedar

In winter the 5 most abundant species in salt cedar (2 primary consumers and 3 insectivores) accounted for 44 percent of the total winter population in salt cedar (Table 3), but these species had an average of only 9 percent of their total population in salt cedar. None of them was represented by more than 14 percent of the total population found in the 4 community types combined.

In spring the 5 most abundant species (2 primary consumers and 3 insectivores) accounted for 66 percent of the total population in salt cedar (Table 3). These species had an average of 13 percent of their total population in salt cedar. Over 28 percent of the Mourning Dove population occurred in salt cedar.

In summer the 5 most abundant species (4 primary consumers and one insectivore) accounted for 75 percent of the population (Table 3). These species averaged 15 percent of their population in salt cedar. Nearly 41 percent of the total White-winged Dove population occurred in salt cedar.

In late summer the 5 most abundant species (3 primary consumers and 2 insectivores) accounted for 61 percent of the population (Table 3). They had an average of 12 percent of their total population in salt cedar. About 59 percent of the Brown-headed Cowbird population occurred in salt cedar.

In fall the 5 most abundant species (2 primary consumers and 3 insectivores) accounted for 70 percent of the total population in salt cedar. About 35 percent of the Orange-crowned Warbler population occurred in salt cedar.

A total of 11 species accounted for the most numerous species in salt cedar on a seasonal basis (Table 3); the Abert Towhee (*Pipilo aberti*) was the numerically dominant species during four seasons and the Mourning Dove and Gambel Quail (*Lophortyx gambelii*) during three seasons. It should be emphasized that the peak population of these species occurred in vegetation other than salt cedar during one or more seasons.

Summary of Densities and Species Using and Avoiding Salt Cedar

Those species in groups A, F and G were considered to prefer salt cedar or not to be affected by it and constituted about 2 percent of the total species present in winter and spring, about 13 percent in fall, and about 25 percent in summer and late summer (Table 4). Two other groups (D and H) appeared to reach maximum densities in areas where salt cedar was mixed with indigenous vegetation. Species in these groups accounted for between 0 and 19 percent of the total species present in all 4 communities. Species in groups B, C and E appear to avoid salt cedar and account for 66 percent to 88 percent of the total species present.

Table 3.--The percent of birds in each group which occurred in salt cedar. These percentages were obtained by dividing the number within each group which occurred in salt cedar by the total number in all four communities. This was done for each season. The column labeled A-H is the percentage of the total population which occurred in salt cedar.

	Percent of Total Birds Within Each Group Which Occurred in Salt Cedar								
Season	A	B	C	D	E	F	G	H	A-H
Winter	-	11.0	-	5.0	4.4	-	-	5.2	8.0
Spring	28.7	12.3	11.2	8.8	0.6	27.6	-	-	13.0
Summer	38.7	15.1	16.5	16.3	13.1	30.0	34.4	-	19.3
Late Summer	51.9	16.1	9.8	-	17.1	-	-	9.8	16.3
Fall	38.0	14.6	15.6	13.3	10.0	-	-	-	13.0

Species tolerating or preferring salt cedar (groups A and G) accounted for 1 to 17 percent of the total density. Those that seemed to profit by mixes accounted for 0 to 29 percent, and those which seemed to avoid salt cedar accounted for 58 to 87 percent of the total densities (Table 5).

Biomass of Insects and Insectivores

At all seasons there was a significantly ($p<0.01$) smaller biomass of insectivores in salt cedar than the average biomass for all communities (fig. 10). There was also a significantly smaller biomass of insects at all seasons in salt cedar than in the other community types. From winter to summer the biomass of insects increased almost 15-fold per 8,000 sweeps in all communities collectively. In salt cedar the insect biomass increased 43-fold from winter to summer but insectivore biomass increased less than 3-fold. In late summer overall insect biomass decreased by 75 percent and in salt cedar by 83 percent. Insectivore biomass decreased overall by 19 percent and decreased in salt cedar by 18 percent. Thus in summer even though there was significantly greater biomass of insects in other communities, if the ratio of insectivore biomass to insect biomass had been the same in salt cedar as in all communities, we would have expected about 1900 grams of insectivores. There was about 1700 grams; significantly ($p<0.01$) less than expected. In late summer the biomass of insects was again less in salt cedar, but the weight of insectivores was very close to expected. In fall and spring there were significantly ($p<0.01$) fewer insects

Table 4.--Number of species for each of five seasons which reacted to salt cedar in various ways along the lower Colorado River. The percent of total species present for each season is given in parentheses.

	Number of Species			
Season	Preferring or Not Objecting to Salt Cedar (Groups A, F, G)	Occurring in Greater Densities in Salt Cedar-Honey Mesquite Mixes Than In Pure Stands of Either (Groups D and H)	Avoiding Salt Cedar (Groups B, C, E)	Total
Winter	1 (2.4)	4 (9.7)	36 (87.8)	41
Spring	1 (2.2)	6 (13.1)	38 (84.5)	45
Summer	10 (24.4)	0 (0.0)	31 (75.6)	41
Late Summer	10 (23.7)	3 (8.9)	26 (68.4)	38
Fall	4 (12.5)	6 (18.8)	22 (68.8)	32

Table 5.--Number of birds for each of five seasons which reacted to salt cedar in various ways along the lower Colorado River. The percent of the total density present for each season is given in parentheses.

	Number of Individuals			
Season	Preferring or Not Objecting to Salt Cedar (Groups A, F, G)	Occurring in Greater Densities in Salt Cedar-Honey Mesquite Mixes Than In Pure Stands of Either (Groups D and H)	Avoiding Salt Cedar (Groups B, C, E)	Total
Winter	4 (0.6)	86 (12.2)	616 (87.3)	706
Spring	27 (5.7)	80 (16.8)	368 (77.5)	475
Summer	179 (17.4)	0 (0.0)	852 (82.6)	1,031
Late Summer	95 (13.3)	208 (29.1)	412 (57.6)	715
Fall	31 (4.0)	123 (15.9)	621 (80.1)	775

in salt cedar, but given that biomass of insects, there were significantly ($p<0.01$) more birds than expected.

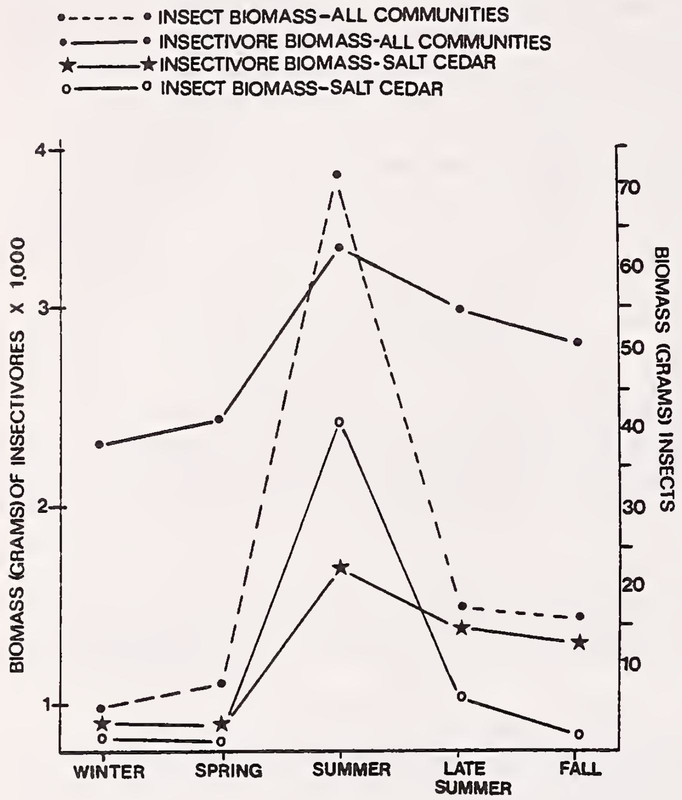

Figure 10.--The biomass of insects in all communities and in salt cedar, and the biomass for the insectivorous birds in all communities and in salt cedar for the seasons of 1976 and 1977.

DISCUSSION

From the above information it is clear that salt cedar has a low value to a majority of species present along the lower Colorado River. Those species which used it as much as other vegetation tended to be granivores, mainly found outside of riparian vegetation, including doves which used riparian vegetation for nesting but which fed mainly in agricultural areas.

It may also be noteworthy that of 11 species belonging to Old World genera, 6 (55 percent) either preferred or at least did not avoid salt cedar at one or more seasons. Among the 54 species belonging to New World genera, only 15 (28 percent) preferred or did not avoid salt cedar at one or more seasons. Since salt cedar is indigenous to the Old World, it may be that a greater proportion of the species belonging to Old World genera are somewhat adapted to it.

It is difficult for local populations of birds unadapted to salt cedar to become adapted to it because there is insufficient genetic isolation between adapted and maladapted groups of individuals. Adaptive gene complexes are constantly broken down because of interbreeding. If, however, salt cedar were to predominate to the near total exclusion of other kinds of vegetation, some avian adaptation to salt cedar might occur, particularly in local sedentary populations.

We have observed that salt cedar leaves exude a sticky material which causes one's hair to become stiff and sticky. This sticky exudate may also cause avian plumages to become stiff and sticky. It would be difficult for insectivores to avoid this exudate if they foraged among the vegetation; thus they avoid it altogether. Another group of birds, frugivores, avoid salt cedar nearly completely because the major source of fruit, i.e. from mistletoe (*Phoradendron californicum*), does not occur in salt cedar.

Birds which are more abundant in salt cedar when it is supplemented by honey mesquite may benefit because more insects are produced in salt cedar than mesquite alone (Anderson and Ohmart, unpubl. data). Since mesquite is comparatively easy for birds to forage in (no exudate, rather sparse leaf cover), certain species may benefit from the enhanced insect fauna in mesquite when salt cedar is present.

A stand of pure salt cedar can be enhanced for wildlife by removal of some of it (perhaps as little as 20 percent) and replacing it with honey mesquite and/or willow. We know from other data (Anderson, *et al.*, this symposium) that addition of quail bush (*Atriplex lentiformis*) and ink weed (*Suaeda torreyana*) will increase certain bird populations. In addition, a stand of salt cedar can be further improved by clearing and replanting in ways which will increase vertical and horizontal foliage diversity. Through a combination of adding more plant species favorable to wildlife and manipulating the vegetative structure, it may prove to be relatively easy and economically feasible to manipulate salt cedar to enhance the vegetative community for wildlife.

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Appendix I.--Bird species occurring in various communities along the lower Colorado River for various seasons of 1975-76. Each species, depicted by a capital letter, occurs in its greatest density in one or two communities and corresponds to the graphs in figures 3-7.

Species	Winter	Spring	Summer	Late Summer	Fall
Gambel Quail, *Lophortyx gambelii*	E	E	E	H	D
Mourning Dove, *Zenaida macroura*	D	F	C	E	B
White-winged Dove, *Zenaida asiatica*	-	D	A	H	-
Ground Dove, *Columbina passerina*	B	B	A	A	-
Yellow-billed Cuckoo, *Coccyzus americanus*	-	-	B	B	-
Roadrunner, *Geococcyx californianus*	D	C	F	B	-
Lesser Nighthawk, *Chordeiles acutipennis*	-	-	E	H	-
Black-chinned Hummingbird, *Archilochus alexandri*	-	-	B	-	-
Common Flicker, *Colaptes auratus*	B	B	B	B	B
Ladder-backed Woodpecker, *Picoides scalaris*	B	B	C	F	C
Yellow-bellied Sapsucker, *Sphyrapicus varius*	B	-	-	-	-
Gila Woodpecker, *Melanerpes uropygialis*	F	C	B	F	C
Western Kingbird, *Tyrannus verticalis*	-	B	B	B	-
Wied Crested Flycatcher, *Myiarchus tyrannulus*	-	-	B	B	-
Ash-throated Flycatcher, *Myiarchus cinerascens*	D	C	C	B	D
Black Phoebe, *Sayornis nigricans*	B	B	-	-	-
Say Phoebe, *Sayornis saya*	B	-	B	-	-

Appendix I. Continued.

Species	Winter	Spring	Summer	Late Summer	Fall
Rough-winged Swallow, *Stelgidopteryx ruficollis*	-	-	B	-	-
Cliff Swallow, *Petrochelidon pyrrhonota*	-	-	F	-	-
Scrub Jay, *Aphelocoma coerulescens*	B	-	-	-	-
Verdin, *Auriparus flaviceps*	E	C	C	E	C
White-breasted Nuthatch, *Sitta carolinensis*	B	-	-	-	-
Brown Creeper, *Certhia familiaris*	B	-	-	-	-
House Wren, *Troglodytes aedon*	B	B	-	-	B
Bewick Wren, *Thryomanes bewickii*	B	C	B	B	B
Cactus Wren, *Campylorhynchus brunneicapillus*	E	E	E	E	C
Long-billed Marsh Wren, *Cistothorus palustris*	B	B	-	-	-
Mockingbird, *Mimus polyglottos*	E	E	G	E	E
Crissal Thrasher, *Toxostoma dorsale*	E	C	E	F	D
American Robin, *Turdus migratorius*	B	E	-	-	C
Hermit Thrush, *Catharus guttatus*	H	-	-	-	B
Western Bluebird, *Sialia mexicana*	E	E	-	-	E
Blue-gray Gnatcatcher, *Polioptila caerulea*	E	-	-	-	F
Black-tailed Gnatcatcher, *Polioptila melanura*	E	E	F	E	D
Ruby-crowned Kinglet, *Regulus calendula*	B	C	-	A	B
Cedar Waxwing, *Bombycilla cedrorum*	E	B	-	-	-
Phainopepla, *Phainopepla nitens*	E	E	E	F	E
Loggerhead Shrike, *Lanius ludovicianus*	B	D	C	A	D
Starling, *Sturnus vulgaris*	B	B	-	-	F
Bell Vireo, *Vireo bellii*	-	B	F	E	-
Orange-crowned Warbler, *Vermivora celata*	B	F	B	B	F
Lucy Warbler, *Vermivora luciae*	-	D	E	-	-
Yellow-rumped Warbler, *Dendroica coronata*	B	B	-	B	C
Yellowthroat, *Geothlypis trichas*	-	B	B	-	-
Yellow-breasted Chat, *Icteria virens*	-	-	B	B	-

Effects of Power Line Corridor Clearance and Maintenance on Stream Habitat[1]

Clifford G. Day[2]

and

Kenneth L. Carvell[3]

Abstract.--Investigations were initiated in the summer of 1975 to determine the effects of power line corridor clearing and maintenance on streams. The principal procedures of this study consisted of vegetation mapping, physical measurements of the study streams, and streambank erosion observations. Particular emphasis was placed on summer diurnal temperature regimes, specifically peak temperature rises.

INTRODUCTION

Electric transmission corridor clearance and maintenance practices have often been insensitive to streams, particularly to smaller streams and their associated riparian habitats. Small, shallow, low-flowing streams are extremely sensitive and vulnerable to landscape changes. Research has demonstrated that when small- to medium-sized streams are exposed for long stretches to direct solar radiation, abnormally high water temperatures often result during the summer. Temperature rise may upset the ecological balance of the sensitive lotic ecosystem. In addition, with the removal of a well-established riparian zone of deep-rooted vegetation, sedimentation and siltation may result or accelerate.

Nine streams were selected for study, three in central New Hampshire, three in north-central West Virginia and three in northern Georgia. In each state, streams selected for study represented a range of sizes based on characteristics of the study stretch and basin and channel morphometry.

The purpose of this study was to investigate changes in diurnal stream temperature patterns caused by power line corridor exposure, and to investigate changes in stream banks resulting from manipulation of riparian vegetation. To accomplish these objectives, information was obtained from nine streams of various morphometry to test two hypothese:

1. Stream segments exposed by transmission line corridors, in otherwise forested areas, receive increased light intensity and thus summer water temperature changes to a substantial degree.
2. Herbicide application along streams results in additional environmental changes including increased streambank erosion and modification of riparian vegetation.

DISCUSSION and CONCLUSIONS

Stream habitat is diverse and includes many features. Therefore, it is necessary to evaluate each stream separately, because several climatic and usually interrelated non-climatic variables determine stream temperature and the overall aquatic habitat. Climatic variations

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[1]Paper prepared for poster session at the National Symposium of Strategies for Protection and Management of Floodplain Wetlands and other Riparian Ecosystems, Callaway Gardens, Georgia, Dec. 11-13, 1978.

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include precipitation, sky conditions and the relative position of the sun. Non-climatic variables, many of which increase the water surface area to direct radiation, also influence the amount of heat received at the stream surface. Such variables include surrounding and overhanging vegetation, channel and bank characteristics, inflow of surface and ground water, topography, length of exposure, depth, velocity and discharge.

For most streams crossing electric corridors, unless they traverse a relatively long section of the right-of-way clearing, only a small segment of the stream is thermally elevated. This thermal modification is a transient phenomenon, varying diurnally and seasonally. The temperature studies conducted on these nine streams were intentionally carried out on clear warm summer days to give the greatest thermal elevations which might occur at any time of the year.

Small- to medium-sized streams were the most sensitive to environmental changes and most vulnerable to landscape manipulation, especially with the removal of protective riparian vegetation. It is apparent from the data that daytime water temperature profiles for small, shallow, low-flowing streams are responsive to microclimatic changes, specifically direct radiation. Radiation measurements under cleary sky conditions along shaded segments were often of only 0.1 to 0.4 ly/min; however, along stream stretches exposed by the right-of-way, radiation was 1.0 to 1.25 ly/min on the same day. When surrounding and overhanging vegetation is maintained in the riparian zone bordering small streams, the normal longitudinal temperature gradient rise remains unaltered. The comparative rise due to right-of-way exposure may cause the temperature regime to fluctuate considerably. Larger streams, which have a small surface area in relationship to water volume, and therefore a large heat capacity, remain "summer cool" regardless of right-of-way exposure.

Under clear sky conditions, maximum stream temperatures occurred about 1500-1600 hours, depending on the position of the sun. On the nine streams, mean temperature changes because of right-of-way exposure ranged from -0.3°C to almost 3°C (1200-1500 hrs, EDT). Streams characterized by substantial flow rates, by shading or by spring discharge resulted in negligible temperature rise. After re-entering the forest after exposure, temperature stabilization usually occurred 60 to 90 m downstream. Cooling groundwater tributaries had a considerable influence on the temperature regime.

Broadcast application of herbicide is less desirable for maintaining stream habitat than selective application, or preferably selective cutting. Repeated broadcast treatment along the channel results in riparian vegetation largely of low-growing herbaceous plant communities. Over a period of years this eliminated well-established, deep-rooted, overhanging vegetation as a natural protective buffer zone. Moreover, the removal of desirable riparian vegetation results in accelerated bank erosion, summer stream temperature rise, increased light intensity and indiscriminate channel crossing by maintenance vehicles and trail bikes.

It is apparent from the data that the environmental changes resulting from power line corridor clearance and maintenance activities can have adverse effects on stream habitat. These habitat alterations will obviously influence stream biota.

RECOMMENDATIONS

Stream habitat management, protecting suitable environmental conditions for stream ecosystems, should be a main priority in decisions pertaining to right-of-way clearance and maintenance. Therefore, based on the observations and analyses included in this study, the following recommendations are presented to improve right-of-way management practices.

1. Factors or practices causing damage to stream habitat should be corrected, especially temperature increase and bank erosion resulting from an absence of streambank vegetation and vehicular stream crossings.

2. Since shading can be the decisive factor in determining the temperature of small streams, a streamside buffer strip composed of well established, deep-rooted, overhanging vegetation is the most desirable solution.

3. Maximum summer stream temperatures should be a primary factor in determining management procedures. More management considerations for manipulating streambank vegetation should be given since the magnitude of temperature increase depends upon the degree of vegetation removal. This approach will put more perspective on small- to medium-sized streams that are most vulnerable to landscape changes.

4. Accelerated bank erosion, sedimentation, and siltation result from vehicular stream crossings. Simply constructed bridges could eliminate this problem. In areas where stream crossing is not necessary for maintenance vehicles, streambank buffer strips would be effective in discouraging other vehicles from crossing, especially trail bikes.

5. Due to the large volume of water, the removal of streambank vegetation along large streams does not appear to raise temperatures. However, other valid reasons justify leaving streamside buffer strips, such as prevention of bank erosion, sedimentation, improving aesthetic values, maintaining normal biological equilibrium, and discouraging herbicide runoff and vehicular traffic.

6. Streams should be considered "non-target" areas for herbicide use. Broadcast herbicide sparying should be replaced by selective spraying, or selective cutting, around stream areas for obvious biological reasons and for stream habitat improvement through manipulation of streambank vegetation. If small tress and woody shrubs are left during selective spraying, they will discourage the invasion of taller-growing woody species.

7. It is necessary to judge each stream on its own features, since many climatic, as well as non-climatic variables, determine water temperature and the overall aquatic habitat. Therefore, it is necessary to direct stream management on an individual basis.

8. Further biological research is recommended.

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Managing Wildlife Compensation Efforts on the Lower Snake River Project[1]

CPT Donald R. Holzwarth[2]

Abstract.--Construction of four dams on the Lower Snake River occurred from 1958 to 1975. The effort to compensate for fish and wildlife losses followed passage of the Fish and Wildlife Coordination Act in 1958. History, current status, and lessons learned are presented on the ongoing effort to implement wildlife compensation measures.

INTRODUCTION

The Lower Snake River project consists of four multipurpose locks and dams - Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. The project was authorized in 1945 and constructed between 1958 and 1975. The dams create a run-of-the-river hydro-navigation reservoir which does not contain any flood control storage.

The objective of this paper is to discuss the history, current status, and lessons learned in the program which has evolved for mitigating the wildlife losses caused by the Lower Snake River dams. The large scope is evident from the estimated cost of almost $80 million in 1978 dollars for the on-and-off project programs. While fishery compensation represents the major monetary portion of the program, this paper will discuss primarily the wildlife aspects.

[1]Paper prepared for poster session at the National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Calloway Gardens, Georgia, 11-13 December 1978.

[2]Project Officer, Lower Snake River Fish and Wildlife Compensation Plan Project Management, U. S. Army Engineer District, Walla Walla, Washington.

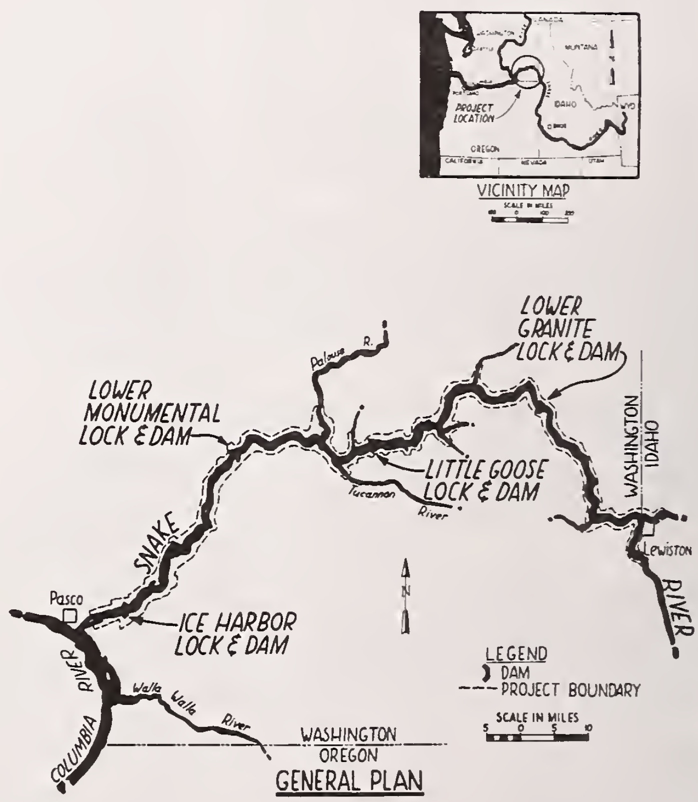

Figure 1.--Lower Snake River Project Area

HISTORY

No mention was made in the authorizing documents of any fish and wildlife mitigative efforts. Therefore, the basis for mitigation is the Fish and Wildlife Coordination Act, PL 85-624, enacted 12 August 1958 (U.S. Army Engineer District, Walla Walla, 1975a:2-3).

The dams changed a free-flowing river into a series of relatively slow-moving reservoirs; flooded spawning grounds for salmon and steelhead; caused mortalities to juvenile salmonids; covered islands in the river which were goose nesting areas; and eliminated gently sloping bottom lands and sparse, discontinuous riparian vegetation which were essential to the wildlife of the area (U.S. Army Engineer District, Walla Walla, 1975a). Figure 2 shows a typical stretch of the Lower Snake River in the Lower Granite Dam pool area. The habitat along the lower river (Ice Harbor and Lower Monumental pool areas) was generally sparser than that shown.

Figure 3 shows a typical "after" area. A critical element is the location of the railroad and riprap embankment so that wildlife access to the reservoir is difficult or impossible.

During the design for the first three dams, individual impact reports were received from the Fish and Wildlife Service. The initial recommendations for offsetting fish and wildlife losses were based on very limited engineering and biological data (U.S. Army Engineer District, Walla Walla, 1975a:3).

While the effects were generally understood, it became evident that measures recommended initially to mitigate these effects did not fully address the complexity of the situation. Isolation of the effects associated with any one of the four dams was seen to be very difficult, especially with regard to the anadromous fish losses. Fish passage facilities already planned as part of the project were constructed at the dams, and some project lands were made available to the Washington State Department of Game (WDG) on a no-cost, long-term license. Essentially no development or subsequent wildlife management occurred on these lands due to a shortage of funds within the Department of Game and disagreement on who should fund the management effort (Office, Chief of Engineers, 1977: 73).

The Corps recognized that some overall comprehensive effort was required to meet the spirit of the 1958 Act. In April of 1966, the Walla Walla District requested that the

Figure 2.--Typical "before" stretch of the Snake River in the upper end of the project area.

Figure 3.--Typical "after" stretch of the impounded Lower Snake River.

Bureau of Sport Fisheries and Wildlife (BSFW) prepare a compensation report on all four dams as one unit. The real problem of the lack of a dependable data base was illustrated by the fact that BSFW did not submit a first draft until February 1971 - almost five years later. Much was learned during that interim period regarding both anadromous fish losses and complexity of estimating wildlife losses. The time was also used by the WDG to conduct user surveys which could serve as a wildlife data base on upper stretches of the river which had not yet been inundated. Estimates of wildlife numbers and hunter-day use were made by the WDG and BSFW. The data on the upper dams (which were not yet completed) were extrapolated to the Ice Harbor Reservoir which had been filled in 1962. Private consultant evaluation of the techniques used is included in two references. (Office, Chief of Engineers, 1977; U. S. Army Engineer District, Walla Walla, 1975a).

Despite the lengthy period of time to complete the first draft, the Corps felt that the report lacked supporting data on both losses claimed and compensation measures recommended. Comments were returned in March 1971; after review meetings BSFW submitted a second draft in December 1971.

In 1972 the Corps sent the second draft with Corps comments to the Oregon, Washington, and Idaho State agencies involved for comment. Finally, in November 1972, BSFW submitted their final report.

The Corps, in December of 1972, sent the first draft of its own report out for agency review. During 1973, review meetings, review by outside consultants, public participation activities, and the beginning of the preparation of an EIS all contributed to the next stage of planning.

The public hearings revealed a general acceptance of the fisheries compensation efforts but a very strong opposition by local landowners to the wildlife measures. They were highly critical to proposals for purchase

of land to replace lost riparian habitat and associated lost fishing and hunting opportunity. Lack of strong supporting data was the most difficult aspect of the criticism to rebut.

During 1974 additional outside consultants were hired, meetings were held with concerned agencies and local governmental officials, and review by higher authority within the Corps of Engineers was made. Work on the EIS continued. Further internal and extensive outside agency review of the Compensation Report and accompanying EIS finally culminated in completion of the final report for public distribution on 28 October 1975. In 1976 the completed report and draft EIS were released for the official 90-day public review; on 1 October 1976 the Compensation Plan was authorized by the Congress and later signed into law on 22 October as part of the Water Resources Development Act of 1976. Initial funding was obtained in FY 1978.

THE COMPENSATION PLAN

Table 1 shows what finally evolved from the ten-year preauthorization effort.

Table 1.--Fisheries and off-project wildlife compensation authorized by the Lower Snake River Fish and Wildlife Compensation Plan

1. Fish hatcheries to provide the return of:

   58,700 spring and summer Chinook
   18,300 fall Chinook
   15,100 steelhead
   93,000 pounds of trout or warmwater fish

2. Streambank access along steelhead fishing streams up to 750 acres in fee or easements.

3. Hunting easements for chukar partridge on 15,000 acres of range land adjacent to project lands.

4. 400 acres of wildlife habitat in fee for development of resident upland game in southeast Washington.

5. Hunting easements primarily for pheasant and quail on 8,000 acres of farmland surrounding the parcels of fee land.

6. Supply of 20,000 pheasants per year for 20 years to provide hunting opportunity and establish permanent populations.

In addition, intensive wildlife habitat development of Corps-owned riparian land adjacent to the reservoirs was considered an integral part of the overall wildlife compensation effort. It was to be a marriage between the off-project and on-project programs. The on-project program was already authorized with approval of master plans for management of reservoir lands; however, a post-authorization comprehensive plan which detailed the effort would still have to be approved. This design memorandum, completed by Wirth Associates for the Corps, was not included in the Compensation Plan but was included as an Appendix of the EIS. It was formally approved by Office, Chief of Engineers, in July 1975. Table 2 outlines the essential elements of the original design memorandum for project land wildlife development.

Table 2.--Wildlife compensation authorized separately for Corps-owned project lands

1. 4,522 acres intensively developed for wildlife habitat to replace areas that were inundated including 917 acres of irrigated land.

2. 22 separate locations designated for development.

3. Installation of artificial goose-nesting structures.

4. Over 80 miles of fencing of wildlife habitat areas from overgrazing.

CURRENT STATUS - OFF-PROJECT COMPENSATION

The BSFW had recommended in their 1972 report to the Corps that off-project lands be purchased from willing sellers only. The Corps accepted this recommendation but despite this local opposition was very strong. Public meetings indicated that the opposition was based on the following:

a. Belief that net wildlife losses did not really occur, and the absence of a proper data base made calculation of mitigation impossible.

b. Resentment at additional Government land taking and fear that a willing seller-willing buyer program would soon lead to condemnation if it did not succeed. This was reinforced by the fact that very little on-project land had been developed or managed for wildlife despite the fact that the dams had been completed for a number of years.

c. The feeling that poor management of any purchased lands would adversely affect adjacent landowners through vandalism, poor noxious weed control, increased fire danger, loss of access control, and other various abuses related to opening land to public use, including hunting.

d. A general suspicion and distrust of Government and Government bureaucracies which are inherent in many fiercely independent farmers and ranchers.

As a result of the public participation program, the Corps was sensitive to the legitimate concerns of the local landowners. Their input affected the Corps' final recommendations which included a slight lowering of the BSFW-recommended off-project acreages based on more intensive on-project development; the provision for concurrence by local County Planning Commission in land sales of management units of the 8,400 acres; and provision that management units be purchased only in viable combination of hunter easements and habitat "core" areas. The Plan, based on wording in the 1958 Coordination Act, called for WDG to fund the O&M for all off-project lands except the 15,000 acres of easements which bordered Corps lands. WDG would also purchase all land except the 15,000 acres with reimbursement by the Corps.

Since authorization and funding, this careful approach has continued. An attempt was made to explicitly list criteria which in essence define the ideal "viable management unit". This included criteria for selection, development, management, planning coordination, and monitoring success of the management units. A contract was entered into with WDG in early 1978 to complete this task. Also included were criteria for 700 acres of riparian fisherman access lands which are part of the fisheries compensation.

The WDG contract also called for identification of actual sites which fulfill the criteria. This was Phase II of the study contract and followed essential agreement on the criteria formulated earlier.

While the final report is still undergoing final corrections, some of the concepts which have evolved are shown in figures 4, 5, and 6.

The off-project wildlife compensation was designed primarily to replace lost recreation user-days. These user-days were based on estimated pre-project wildlife numbers and acres of riparian habitat. Fencing alone will accomplish much by preventing cattle from destroying riparian vegetation. The other

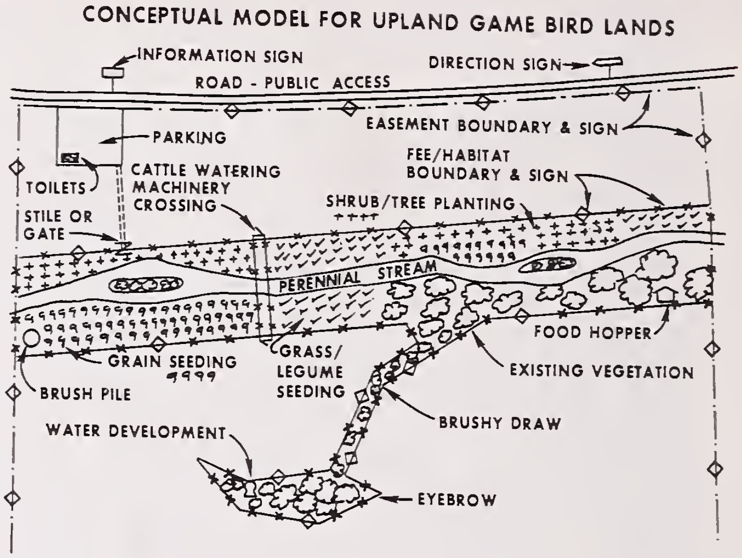

Figure 4.--Results of criteria planning for upland game bird hunter lands

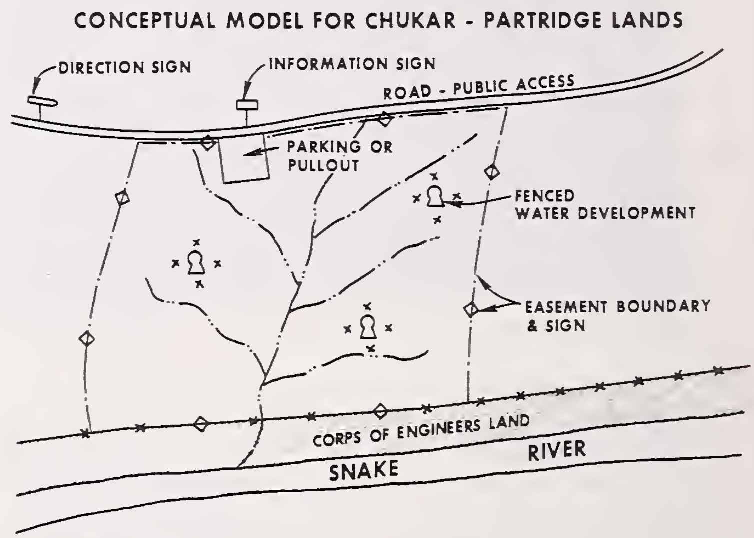

Figure 5.--Results of criteria planning for chukar partridge lands

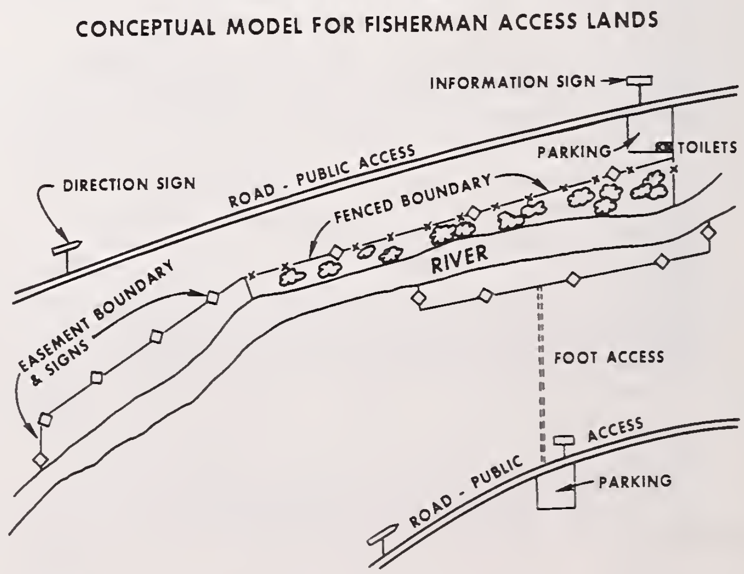

Figure 6.--Results of criteria planning for fisherman access lands

developments should substantially increase the carrying capacity of the riparian habitat. This will affect both game and non-game species even though the primary purpose is replacement of lost hunting opportunity.

An extensive effort was made by WDG in researching estimated costs of the hunting and fishing easements. Not many precedents were found; sales which were found in the area of scenic easements were very expensive. The Compensation Plan calls for "easements in perpetuity" and it is felt that the loss of property rights "forever" may be very expensive, if obtainable at all.

Numerous potential sites were identified which meet the criteria. The sites will be prioritized and presented for approval by higher authority within the Corps. It was felt that the ability to follow up relatively quickly with cash to a willing seller will be an important element in the success of the Plan. Only appraised, reasonable prices will be paid - thus the importance of the willing buyer part of the Plan.

The end product of the contract with WDG which evolved in 1978 is a result of numerous review sessions and includes Fish and Wildlife Service input. It is designed to help insure that the very real concerns of potential sellers and their neighbors are met. In this way it should help to increase the ultimate chances for success of the program.

WDG was also given funds in FY 78 to conduct planning for the game bird replacement part of the Plan. They will decide the best alternative to provide the required number of pheasants for the 20-year period. The alternatives being considered range between outright purchase to construction of a new bird farm. The lump sum nature of this element gives WDG complete flexibility in meeting the compensation goal of 20,000 planted birds per year for 20 years. The birds will be planted with a "put and take" goal on suitable project and acquired lands until carrying capacities have been increased.

The succeeding steps of the program include:

a. Holding of a series of public informational meetings to discuss criteria and potential specific areas which meet these criteria.

b. Completion of follow-on Corps reports in FY 79 which incorporate public response and become the basis for actual land acquisition funding authority. These include a Wildlife General Design Memorandum and a Wildlife Real Estate Design Memorandum. The basis for these reports will come from the products of the present contract with WDG.

c. Beginning of land purchase in FY 1980.

CURRENT STATUS - PROJECT LANDS

Some irrigation and development work was accomplished in FY 76 and 77 following approval of the original design memorandum. The initial experience gained during this time pointed up some serious problems. The need was seen for rather extensive changes in the concepts outlined in the original design memorandum. This was primarily due to problems in the habitat layouts and proposed irrigation system. The irrigation of tightly spaced plantings on 22 small areas would simply not meet the goals of the wildlife compensation program. Overconcentration of game in narrow strips would allow hunters and predators alike inordinate success which could jeopardize the goals for maximum production and sustained harvest.

By November 1978 the new design concept was 95 percent complete. It called for more intensive development of eight larger sites (instead of 22) but still totaling about 1,000 acres of fully irrigated plantings for optimal wildlife habitat. The additional developments which are planned include fencing, trees and shrubs, meadows, pastures, fields, annual food plots, guzzler complexes, and nest structures for both geese and cavity nesters. The final form of the revised plan has yet to be approved by higher authority in the Corps. To avoid additional delay while the new design is being finished and approved, some preliminary work has been accomplished. This work will fit into the new design concept regardless of its final form.

In FY 78 a contract was signed with the WDG to complete an extensive pre-development survey. The results will serve as a data base upon which to judge success of the developments which will follow. In addition, some initial developments have been completed. Fencing contracts were completed and farming and irrigation equipment was purchased.

In FY 78, work to change the original design concept continued and simultaneously an attempt was made to award irrigation "design and construction" contracts. However, the bids were too high for award due to high bidder contingencies for unknown excavation materials for the buried pipes. The unknown factors were clarified and a Phase I irrigation contract was awarded in October 1978 for almost $700,000.

The total cost picture for on-project wildlife developments is now beginning to emerge. The original cost was estimated at $2.6 million initially and $120,000 annually (1974 price level). By October 1978 the initial cost estimate of the new design concept was around $7 million. While the operation and maintenance costs should be reduced with the new design, they will still be quite high. Analysis to insure these costs are the minimum required to meet mitigation goals is currently underway. The actual management is to be accomplished by WDG personnel and funded by the Corps.

LESSONS LEARNED

An exhaustive, drawn-out planning effort was finally culminated after 10 years with passage of the Compensation Plan into law. Part of the reason for the lengthy planning period can undoubtedly be found in bureaucratic "institutional" restraints which were reflected in a weak implementation of the Fish and Wildlife Coordination Act. But to place all of the problem here does not recognize the complexity of this effort. Despite the best laws, a government and its agencies will generally not be in the vanguard of a national mood. Environmentalism bloomed and the National Environmental Policy Act and other important legislation followed during this period. With the new requirements, including the 1973 Principles and Standards for Water Resources Planning, new emphasis was placed on other than economic values. The goal of true interdisciplinary planning was given a big boost during this 10-year span.

After examination of the fish and wildlife planning activities related to Ice Harbor Dam over a 20-year period, a private consultant concluded that: "The documented record clearly illustrates the evolution of more meaningful wildlife-related priorities and concurrent improvement of inter-agency cooperation which has occurred over this period." (Office, Chief of Engineers, 1977:71). Given these circumstances, the Compensation Plan which did evolve was generally defensible.

After the first year of implementation, the perspective gained leads to the following conclusions:

a. The 1958 Coordination Act was used as the legal basis for a mitigation program for the Lower Snake River project which was authorized without compensation (except fish passage). The massive nature of the Compensation Plan, when fully implemented, should provide measures which reasonably approximate true compensation for losses incurred by the dam. From this overall viewpoint, despite initial lack of mitigation data and weak implementation, the Coordination Act has served its purpose.

b. The nature of both planning and implementation is very complex. The process of reaching agreement between fish and wildlife agencies, the various "publics", the construction agency, and Congress is time consuming but can be accomplished. In reaching an agreement acceptable to all of these varied interest groups and one which Congress will authorize, some compromise is to be expected.

c. The nature of the willing buyer-willing seller program places some uncertainty on the implementation phase of the program. The authorization requires the Chief of Engineers to report to the Congress after five years on the extent to which it has been possible to acquire compensation lands. This report will also recommend any further measures deemed advisable to accomplish the authorized Compensation Plan. This interim reporting requirement helps to remove some of the uncertainty in implementation.

d. The operation and maintenance of a Compensation Plan is a high-cost item that should be carefully considered. It is essential that: (1) accurate cost estimates are provided, (2) an agency is clearly designated to finance the operation and maintenance, and (3) this agency is fully capable of providing the funds.

e. To cut down on the lengthy time for planning and the uncertainties involved in actual implementation, the following procedures would be beneficial:

(1) Mitigation measures should be included in the water project authorization and implementation should occur during project construction. This will prevent losses, which continue to occur during the lengthy planning period.

(2) During early planning, a pre-project wildlife data base should be collected. This will help all later phases of the program to go more smoothly.

(3) Land justified for mitigation should be purchased concurrently and through the same procedure as lands acquired for other project purposes.

The above measures are now part of Corps of Engineers policy and should do much to cut down time required to implement fish and wildlife mitigation (Office, Chief of Engineers,1978).

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Improving Channel Efficiency Without Sacrificing Fish and Wildlife Habitat: The Case for Stream Restoration[1]

Nelson R. Nunnally[2]

Abstract.--Stream restoration is a means for improving the hydraulic efficiency of streams which is less expensive and less environmentally damaging than conventional channelization. Restoration creates a more stable channel by removing debris, providing fairly uniform cross sections, and stabilizing stream banks with minimal disturbance of the streambed and riparian vegetation.

INTRODUCTION

Stream restoration refers to a process for designing, constructing, and maintaining stream channels which is environmentally less damaging and less expensive than traditional channelization. Channels designed and constructed according to the guidelines presented in this paper are not as hydraulically efficient in handling large flows as are traditionally designed streams, but the small loss in efficiency is more than offset by increased environmental benefits and lower costs.

PROBLEMS WITH CHANNELIZATION

Channelization has long been a target of environmentalists and wildlife personnel because of its disruptive impacts on fluvial ecosystems and fish and wildlife habitats. In addition, streams which have been straightened are notoriously unstable and have severe bank erosion problems. The impacts of channelization can be summarized as follows:

1. Destruction of riparian vegetation due to the enlargement and relocation of channels and the need for access by large equipment. Where draglines are used all trees are typically removed on at least one bank, and sometimes along both.
2. Fluvial ecosystems are disrupted by the sediment disturbed during channel work and by increased water temperatures that result from loss of shade and increased water surface area (Corning, 1975; Keller, 1976).
3. Streams which have been straightened and given uniform cross sections contain no pools and riffles and offer poor fish habitat and no protection from high flow velocities during bank-full discharges (Corning, 1975; Keller, 1976).
4. Bank erosion is a major problem on channelized streams. The worst erosion problems occur on streams where the gradient has been steepened (Emerson, 1971; Yearke, 1971; Simmons and Şentürk, 1976).
5. Channelized streams have little to offer aesthetically. There is nothing visually pleasing about a uniform channel with no trees (Keller, 1976).

ADVANTAGES OF RESTORATION

Because of the different philosophy governing design and construction of restored streams they have several advantages over traditionally channelized streams.

1. There is minimal destruction of trees. Only those trees are cut which are growing in the channel or which are in immediate damage of falling in (fig 1).
2. Banks on restored streams are more stable because gradients are not increased, stable banks are minimally disturbed, and tree roots provide continued protection from scour. In addition disturbed banks are seeded as quickly as possible and are protected with riprap in outside meander bends and at other locations where evidence of scour persists (fig 2).

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[1]Paper presented at the National Riparian Ecosystems Symposium, December 11-13, 1978, Calloway Gardens, Georgia. Research reported in this paper was sponsored by University of North Carolina Water Resources Research Institute.

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Figure 1.--Trees are removed during restoration only if they are blocking flow or if they are in emminent danger of falling into the stream.

Figure 2.--Disturbed banks are stabilized by sowing grass and by using riprap where necessary to protect banks from scour.

3. Stream reaches are almost never straightened or relocated although there is some attempt to provide a fairly uniform stream width in straight reaches and greater width in meanders (fig 3). Thus, it is sometimes necessary to remove constrictions or bank obstructions and to narrow the stream where erosion has produced an overly wide channel.
4. During construction there is minimal disturbance of the streambed or of vegetation outside the right of way. Inside the right of way heavy undergrowth is removed, but trees and saplings are not disturbed (fig 4).

Figure 3.--Streams are not straightened and channels are not enlarged except where constrictions restrict flow. If possible, banks are sloped to 2:1 (horizontal to vertical) in straight sections and outside meander beds and 3:1 on inside meander bends.

Figure 4.--Undergrowth is cleared from the right of way on either side of the channels. This permits more rapid flow of flood water and produces a greenway that can be used by local residents. Beyond the 30 to 40 foot right of way vegetation is not disturbed.

5. The final result is a morphologically stable stream which is pleasing aesthetically. Pools and riffle sequences associated with meanders recover quickly after high flow events flush disturbed sediment through a reach. Restored streams also have better habitant and higher fish and wildlife populations than do channelized streams.
6. The cost of stream restoration is typically a fraction of the cost of channelization. Restoration costs of Charlotte, North Carolina streams have varied from five to twenty dollars per linear foot depending on stream size and the amount of riprap

required, whereas a recent channelization project in Charlotte cost in excess of $300 per linear foot.

IMPLEMENTING THE RESTORATION CONCEPT IN URBAN AREAS

Implementation of the restoration concept can be broken into three areas--channel design, construction, and maintenance--each of which is discussed separately.

Design

The major elements of design cover the channel size and shape, designating which, if any, trees are to be removed, determining the size and placement of riprap, and specifying seed mixtures for vegetative bank stabilization. One of the advantages of restoration is that many of the design decisions can be made in the field by the foreman of the construction crew, once he has gained experience.

The Charlotte streams that have been restored are headwater streams that primarily drain developed residential areas. Furthermore, these streams were channelized several decades ago. It was assumed that these streams had become adjusted to increased discharges and that no enlargement of the channel cross section was necessary.

It is commonly accepted by engineers and geomorphologists that natural channels in undisturbed areas are "in regime," i,e. that their cross sectioned areas and shape are adjusted to flow conditions (Vanoni (ed.), 1975). Land use changes, especially the conversion to urban uses, can upset this equilibrium (Hammer, 1972; Holeman and Geiger, 1959; Wolman, 1967). Even though there is no general agreement as to the length of time required to re-establish regime following disturbances, many geomorphologists and engineers believe equilibrium on urban streams is re-established through erosion rather quickly, with most of the adjustments taking place over a short period of five to ten years.

The only changes in channel size involve removing bank constrictions and obstructions to flow and providing a reasonably uniform width. Disturbed banks are shaped to a 2:1 (horizontal to vertical) slope in straight reaches and outside meander bends. Inside meander bends are given a 3:1 slope.

During a field tour any trees that must be removed are designated, bank slopes are designated, and the placement of riprap is decided (fig 5). It is important to remember that at high discharges the streamlines of highest velocities tend to straighten out and flow across meander bends, and riprap protection must be provided far enough downstream from meander bends to prevent scour during those high discharge events. Also, sharp bends (angle of entry > 30°) may cause the flow to be deflected from one bank to another in the downstream direction for a short distance (fig 6). Since no channel excavation is done, riprap is extended into the channel for a feet at the bank toe. During flood events, this riprap is buried to a depth of one or two feet beneath the streambed as the sand is entrained and redeposited.

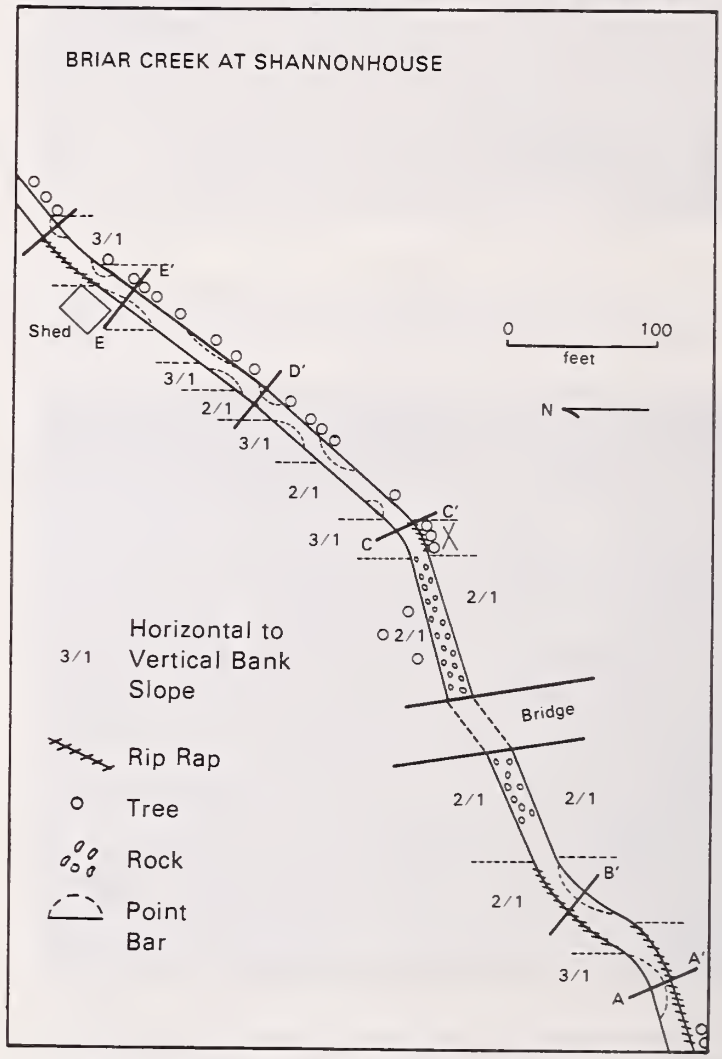

Figure 5.--The basic design is developed from a field inspection during which it is decided which trees are to be removed, what bank slopes are to be used, and where riprap is needed. A plan is then drafted for the construction foreman.

Most design procedures for sizing riprap are overly conservative. In our experience large riprap was more unstable because of the momentum it developed while rolling downslope if dislodged. We have found small riprap, 6" to a foot in diameter, to be stable on streams carrying bank full discharges of 1,500 cfs at computed mean velocities of nine feet per second.

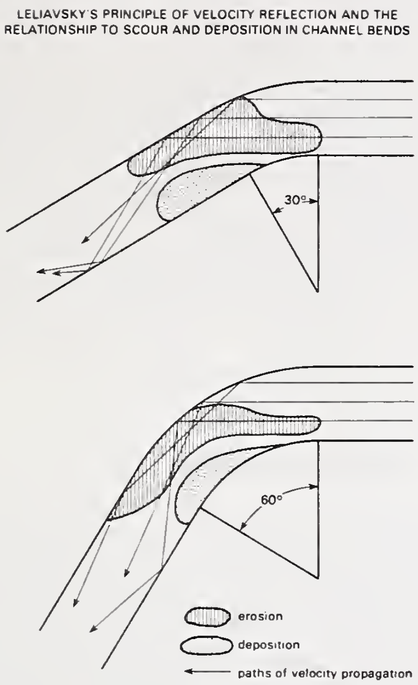

Figure 6.--Riprap placement in and below sharp bends can be estimated by sketching the channel and drawing flow streamlines as shown in this figure.

Construction

The construction phase involves snagging and clearing debris, shaping the channel, and stabilizing the banks. Snagging and clearing require both hand and machine work. Trees are cut with chain saws and debris is removed with a hydraulic hoe. If it is necessary to cut trees on the bank, they are cut close to ground and the root systems are left to help stabilize the bank.

Because the streams in Charlotte are headwater streams, we have been able to use small equipment that is not so environmentally damaging. The major items used are a small bulldozer, tractors, and a hydraulic hoe. Small equipment does not disturb the soil as badly as large equipment would and generally does not require the removal of trees for either access or operating room.

When the banks have been shaped, riprap is dumped and hand placed, if necessary, at the designated sites. Following placement of riprap banks are prepared and seeded (including riprapped areas). Seedbed preparation includes plowing, raking and fertilizing. The amount of fertilizer and the type of seed mixture used depends on site conditions.

Maintenance

Improvements from restoration may be short-lived unless a regular and effective maintenance program is followed. Within a short time the stream should be reinspected, and areas where vegetation cover has not been established should be reseeded. Banks should be examined following high discharge events to see if additional riprap protection is needed. During the design phase riprap use should be confined only to those locations that the investigator is confident will require riprap protection. It is imperative, therefore, to check the need for additional riprap before severe erosion problems result.

Debris should be removed periodically to prevent debris jams and flow obstructions that could create bank erosion problems. Localized scour can initiate severe erosion problems. The frequency of removal varies depending on the type of neighborhood, stream size and other factors.

It is also necessary to cut bank brush and saplings that become established within the channel. Large vegetation and brush can not only severely reduce the efficiency of the channel but can cause erosion by displacing the locus of mean velocity toward the opposite bank.

EVALUATING THE RESULTS

Streams that have been restored can be evaluated on a number of criteria including morphological recovery and stability, biological impact, hydraulic efficiency, aesthetics and recreational potential.

Recovery and Stability

Cross sections were established and surveyed following completion of the initial restoration on Briar Creek in 1975. Annual resurveys of these cross sections have revealed little significant change in geometry (fig 7); however, field reconnaissance of the stream following a severe storm in August 1978 which generated discharges in excess of the 10-year return internal discharge did cause some failure problems. These problems were primarily associated with locations where obstructions created localized scour, where overbank flows entered the stream, and where a large tree on the bank was undermined.

Morphologic recovery has been difficult to document because of the condition of the streams prior to initiation of the project. Heavy bedload and the distribution of numerous debris and log jams had destroyed the normal

pool-riffle sequence, although most of the large meanders did contain some kind of pool.

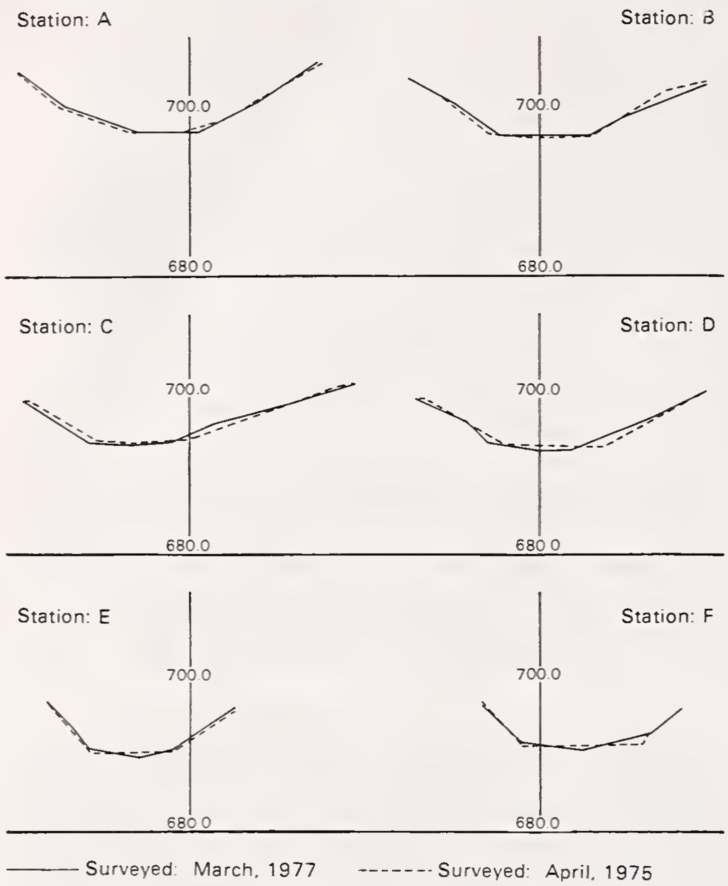

Figure 7.--Sections established in April 1975 and resurveyed in March 1977 revealed little significant erosion. Field surveys did reveal some bank failures following an intense storm in August 1977, however.

During the restoration of one 2,000 foot reach of Briar Creek, the clearing, snagging and bank stabilization generated sufficient bed load to obliterate the pools within the entire reach. Within one year 15 permanent pools could be identified within the reach which were at least one-half meter deep (average depth of flow was 8 to 15 centimeters at the time observations were made). The pools were spaced an average of about 40 meters apart, or about six and a half times the channel width. This ratio falls well within the average pool-to-pool spacing of five to seven channel widths that occurs on natural streams.

Biological Impact

Biological impact has been even more difficult to evaluate. No inventory of fish, macro-invertebrates or mammals was taken prior to initiation of the work on Briar Creek, therefore, there are no quantitative baseline data for comparison. Evaluation of impacts on biology and water quality is further confounded by the poor condition of the stream prior to restoration. In 1975, Briar Creek was typed as a "class D" stream by the North Carolina Department of Natural Resources and Community Development. At that time, this was the lowest class, meaning that Briar Creek was severely polluted from both non-point and point sources. Theoretically, Class D streams were fishable, and the fish from them were edible. In fact, few fish were present except for suckers, carp and a small number of sunfish. Restored sections of Briar Creek at present contain low populations of bass and sunfish and moderate populations of chubs and darters. Macroinvertebrate populations are still low, largely because of the continued heavy bed load transport.

Hydraulic Efficiency

The hydraulic efficiency of the improved stream reach on upper Briar Creek was compared by routing a 20-year design storm through the unimproved and improved channels. The routing which was done by U.S.G.S. personnel indicated that the maximum stage was lowered by about two feet, a figure which substantially reduces potential flood damage. Although Briar Creek has been out of its banks in the Shannon Park neighborhood several times since the restoration was completed in 1975, no property damage to homes has occurred according to surveys of the residents, despite the fact that storms exceeding a 10 year return interval have occurred. Prior to 1975, the stream flooded regularly, causing annual damages of several thousand dollars in the Shannon Park area.

The flooding which still occurs is caused in part by two inadequate street culverts which cannot handle the increased discharge of the improved channel. These have not been replaced because of the poor benefit-to-cost ratio that would be realized. The estimated cost of replacing the two culverts was $577,000 whereas the appraised value of the seven houses and lots that would be affected was only $159,000.

Aesthetic Impact and Recreational Potential

Seventy-five percent of the residents along the Briar Creek who have been surveyed believe that restoration has produced noticeable improvement in the aesthetic quality of Briar Creek. Before the work was done most of the streambanks and flood plains were covered with a tangled undergrowth of briars, brush, vines and trash, and the streams were clogged with debris which included plastic bottles, automobile tires, washing machines, and in one case, a Dempsty Dumpster. By leaving trees and providing vegetative stabilization, the resulting effect is visually pleasing--particularly after the riprap has become vegetated and hidden from view.

Prior to restoration, little use was made of riparian lands along Briar Creek. Since improvements, the areas are frequently used as nature trails by adults and as play areas by youngsters. In fact, trail bikers have become a nuisance in several areas and have been directly responsible for creating numerous bank erosion problems. In at least one instance nearby residents have joined together to maintain a small park and picnic area along an improved tributary to Briar Creek.

SUMMARY

Stream restoration is a means for restoring flow efficiency in streams that have become debris-choked and eroded due to the direct or indirect actions of humans. Such degraded streams are typically characterized by debris jams, severe bank erosion, overwide channels, and heavy sediment discharge brought on by altered stream regimes, land use changes or prior channelization. Compared to channelization stream restoration involves trading off some loss in flow efficiency for a more stable channel morphology and significantly better acquatic and fluvial ecosystems.

Stream restoration is accomplished by removing debris jams and providing fairly uniform channel cross-sections and gradients while preserving meanders, leaving as many trees as possible along stream banks, and stabilizing banks with vegetation and riprap where necessary. Economically, the cost of restoration is typically less than one-tenth of the cost of channelization.

Experiments with stream restoration on Briar Creek, Gum Branch and Mallard Creek in Charlotte, North Carolina, have been extremely successful. Despite several storms with heavy rainfall, some of which exceeded ten-year design storms, few significant areas of bank failure have occurred in the restored sections even though massive failures occurred during the same period on untreated streams nearby. Although fish and wildlife populations were disturbed during work, populations recovered rapidly within one year and are near pre-treatment levels. Public enthusiasm and support for the project is very high with most residents of flood prone neighborhoods perceiving considerable improvement in flood hazards and reduced erosion without significant reduction in wildlife.

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County Drainage Ditches in South Central Minnesota: A Unique Riparian Ecosystem[1]

Henry W. Quade[2]

Abstract.--The purpose of my research is to obtain the types of diverse data needed to model the complex drainage ditch ecosystems which dominate the South Central Minnesota landscape. Documentation, as to the extent of drainage, which is fundamental to water resources planning has been found to be unacceptable and new data is presented. The question of the constitutionality of drainage in Minnesota is shown to be in a period of transition and conflict. The positive effects on water quality of a single drainage ditch case study are presented.

INTRODUCTION

There exists today a very real paradox in Minnesota when one talks of "Quality of Life". That paradox relates to the fact that we pride ourselves on our recreational waters and our agriculture which many feel are mutually exclusive. In our area agricultural drainage ditches form the basis for much of our agriculture.

The 1972 Amendments to the Federal Water Pollution Control Act specify that state agencies develop guidelines to identify, evaluate, and control non-point source pollution resulting from various activities including agriculture. As agriculture is Minnesota's most important industry and since much of our agriculture is associated with or affected by man made drainage systems the relevance of limnological studies on ditches is quite apparent. There does not exist at present an adequate base from which to develop policies and management guidelines from either the point of view of water quality or water quantity for present ditching practices. Any "208" plan formulation that does not include the effect of ditches on water as well as on the land in its mix could lead to questionable policies.

The ditch studies which have been reported and the concerns which have surfaced generally relate to only one component of the drainage ecosystem. One should examine the changes in water quality and quantity of the receiving body as well as the effects on the drained riparian habitat (fig. 1). We have cases in our area where ditches are entering lakes and other ditches are extracting water from the same lakes. Some ditches terminate at levels lower than the lakes they are entering and the water must be pumped up into the lake which acts as a sealed holding pond. Many studies document the distruction of riparian habitat due to drainage, but few look at the potentially new riparian habitat created. The miles of open ditches, many with berms, surpass the miles of natural river channel in many of our townships. There is a rising concern for our roadside ditches as potential wildlife habitat but drainage ditches have been neglected. At present drainage ditches are constructed for the removal of water and managed for easy cleanout. It is my contention that they should be constructed for and managed with wildlife, flood control, and water quality concerns added to the mix.

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[1]Paper presented at the National Symposium on Strategies for the Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, Callaway Gardens, Georgia, December 11-13, 1978.

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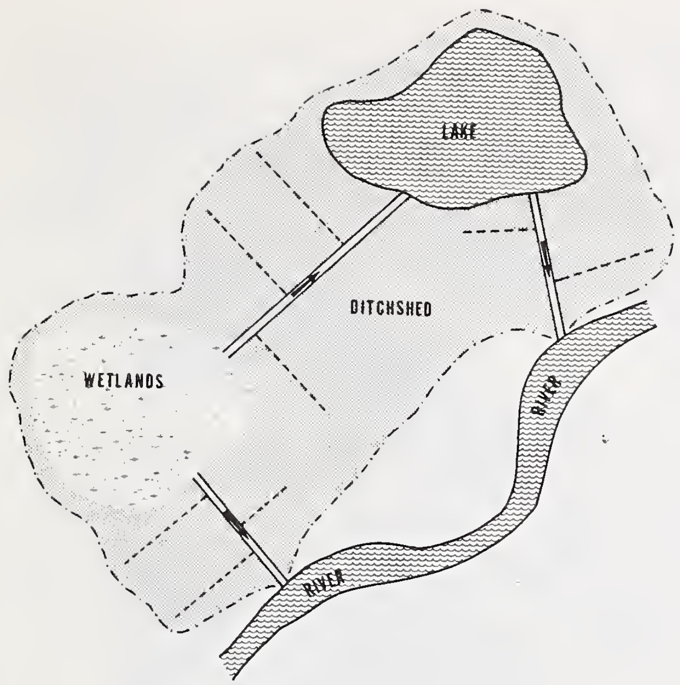

Figure 1.--Theoretical drainage ditch pathways.

South central Minnesota newspapers are reporting many new controversies involving ditches ranging from their effects on lake levels, on lake water quality, on wetland modification, to problems of riparian vegetation management. The affect of upland drainage on the flood levels of our rivers and streams remains to be adequately studied.

Our local County Board Commissioners have expressed their difficulty in handling ditch requests due to a lack of information to draw upon. Southern Minnesota drainage ditch proposals and improvement proposals are increasingly finding their way to the State Supreme Court. Judge Lawrence Yetka stated with Judges James Otis, C. Donald Peterson, and Fallon Kelly concurring that "Surely, under the new environmental laws serious doubt as to the desirability of any general drainage schemes must exist" (March 11, 1977, Mankato Free Press).

It is further apparent that as more lake shore associations seek help for lake restoration there will be increasing need for quantitative data and predictive modeling on the limnology of drainage ditches which enter their lakes.

The citizens themselves (from our predominantly agricultural region) are placing "water quality" as the most important water problem. In his report "The Citizen and Water Management: An Atlas of Water Attitudes in Southern Minnesota" (OWRR Project B-042-Minn.) Moline (1974) investigated the spatial variation in the perception of water resources and water problems in South Central Minnesota. His study involved both a stratified (areal) random poll of residents and a select group poll of individuals concerned with water management and planning within the basin. When asked to rank the three major water resource problems in this area, the respondents, surprisingly, in both the random poll and the select group poll indicated that "water pollution" was clearly number one with "inadequate water resource planning" number two. "Wet agricultural fields" was the number three priority for the stratified random sample poll.

The purpose of my research program is to generate the kinds of diverse input data which will ultimately allow me to model the drainage system in South Central Minnesota. With Environmental Impact Assessments becoming a requirement for major drainage ditches the ability to model them is paramount. In this paper I will address first the extent and reasons for drainage in our area and briefly review the findings of a case study on the effects of a drainage ditch on lake nutrient loading.

EXTENT OF DRAINAGE

A publication prepared by the U.S. Department of Commerce, "Drainage of Agricultural Lands", for the United States Census of Agriculture, 1959, indicates that by the end of the 1950's Minnesota had drained 11.7 million acres of land or 23 percent of the land in Minnesota. This represented 11.5 percent of all drained agricultural land in the United States and Minnesota was second only to Indiana nationally.

In the four South Central Minnesota counties: Blue Earth, Brown, Le Sueur, and Nicollet we have several hundred county and judicial ditches. The United States Geological Survey in their 1971-1972 drainage survey of Minnesota lists Blue Earth County with 50.4% of land affected by drainage (713 miles of drainage ditch), Brown County with 48.2% (235 miles), Le Sueur County with 43.5% (309 miles), and Nicollet County with 59.4% (422 miles).[1] The above does not include private drainage ditches.

The data for the above was based on responses solicited from respective county engineers. Many problems surfaced such as whether an improved "Channel" should be regarded as a constructed ditch, the present efficiency of earlier constructed ditches and tile systems, and the determination of actual ditch sheds to name a few.

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[1]United States Geological Survey, 1971-1972, Drainage survey by counties for Minnesota, unpublished.

A 1978 survey of drainage practices conducted by the University of Minnesota Department of Agricultural Engineering involved the making of a questionnaire to the District Conservationists of the Soil Conservation Service located in each county (Allred and Geiser, 1978). The survey is to be used in Minnesota "208" water quality planning.

Blue Earth County was listed as having 14.9% of its total area artifically drained, Brown-34.7%, Le Sueur-14.3%, and Nicollet-20.2%. Further, all except Brown County indicated that less than 50 percent of estimated wet crop and pasture land was presently artifically drained. These figures vary significantly from those of the 1971-1972 U.S.G.S. report.

Because of the lack of dependable data as to the extent of drainage in the counties of South Central Minnesota, I have found it necessary to enter into an extensive mapping program. This becomes critical if significant differences in extent of drainage data would result in differences in water resources planning by county, state or federal planners.

Our procedure has been to microfilm the "as built" ditch maps from the four counties listed above, obtain prints from the microfilm, project the ditches (and ditch sheds when possible) onto 7.5 minute U.S.G.S. topographic maps, complete ditchshed determination (using the topography, aerial photography, and ground truth), planimeter the areas and tabulate. After having determined ditch shed we could then determine lakesheds and direct river sheds. In an attempt to put ditching in a historic context we obtained, traced, planimetered and tabulated the area of lakes and wetlands from the General Land Surveys for each county; surveyed between 1850-1870. It should again be pointed out that I am dealing with county drainage systems only and have not attempted to quantify private drainage.

Figure 2 shows the composite map developed for Blue Earth County. Differences in the distribution of soils and geomorphology within the county have resulted in differences in the amount of drainage. Tables 1 and 2 show the data tabulated for the General Land Survey and the cummulation drainage for townships by decade. We have also tabulated all data by the various riversheds.

Although one must be cautious in correlating all historic loses of wetlands and lakes to drainage it is clear that overall a relationship does exist. Figures 3 and 4 show respectively the loss of wetlands in Lincoln Township and the loss of lakes in Butternut Valley Township. Over 16 percent of Lincoln Township was mapped as swamp and 6.2 percent of Butternut Valley Township was mapped as lake in the General Land Survey (Table 1). Drainage to date in these two townships are 91.3 and 86.9 percent (Table 2). We have not attempted to overlay the General Land Survey onto topographic maps and determine the original lakesheds. At present 11.3 percent of Butternut Valley Township is in direct, non-ditched, lakesheds.

REASONS FOR DRAINAGE

K. Elton King, a limnology student, and I have attempted to quantify the reasons for drainage from an historic perspective. This has involved an extensive examination of the State of Minnesota drainage law and an examination and tabulation of all Blue Earth County drainage ditch petitions.

Originally drainage offered a panacea for many of the early Minnesotan's problems, and it was believed that great benefits could be derived from the reclamation of wet and overflowed lands. These benefits included (1) a greater certainty of a full crop because drainage would result in reduction of frost damage; (2) an increase in yield per acre and a corresponding increase in market value of land; (3) improvement of highways; (4) increased profits by freight companies due to increased shipping of agricultural commodities; (5) increased business in towns and villages proximate to reclaimed areas; (6) improved railroad service due to decreased losses from floods and softened roadbeds; (7) "improvements in public health, due to the elimination of disease breeding swamps and marshes". (Palmer 1915)

The agricultural benefits derived from drainage were obvious. Where land could be relieved of water fairly economically, such as in the wet prairies, drainage provided relatively flat and fertile land without having to undertake the laborious job of clearing the land of trees (Moline, 1969). Moreover, diffused surface waters were considered..."a common enemy, which an owner, in the necessary and proper improvement of his land, may get rid of as best he may..." (Pye v. City of Mankato, 1887, 31 N.W. p. 863). With these attitudes, drainage was considered progressive and as a result the early drainage laws liberally provided a multiplicity of ways to accomplish wetlands reclamation. Drainage statutes enacted for the purposes of improving public health proceeded upon the proposition that wet, low, and marshy lands provide habitat for malaria carrying mosquitoes, causing a danger to the health and life of the people in close proximity.

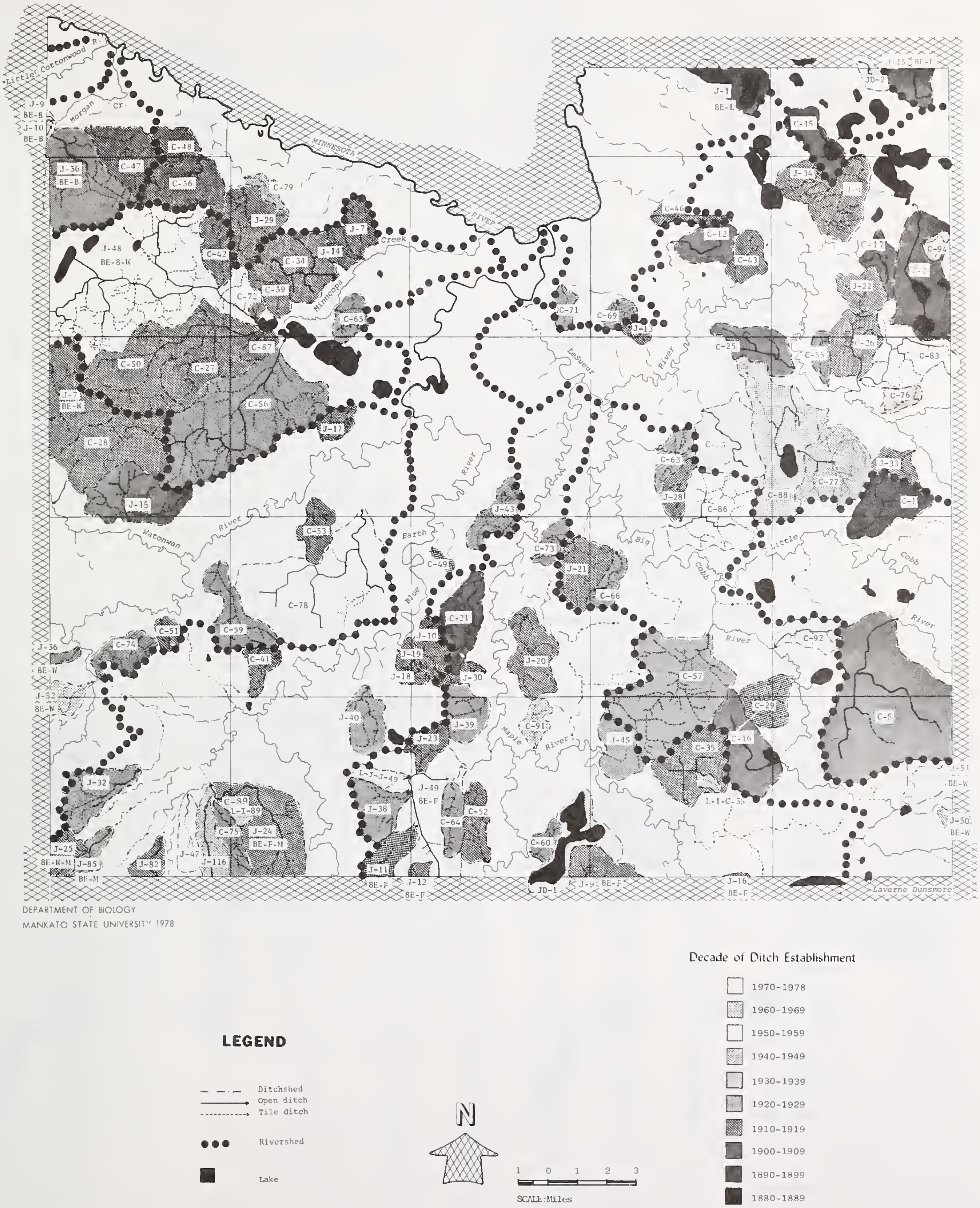

Figure 2.--Blue Earth County Ditch Map.

Table 1.--General Land Survey, 1854, Blue Earth County.

Congressional Township	Civil Township	Percent Swamp	Percent Lake
106N 26W	Beauford	3.1	1.1
109N 27W	Belgrade	0.0	0.0
108N 29W	Butternut Valley	6.6	6.2
109N 29W	Cambria	0.4	0.0
106N 29W	Ceresco	2.7	0.0
105N 25W	Danville	8.8	0.7
107N 26W	Decoria	1.7	0.3
107N 28W	Garden City	6.5	6.3
109N 25W	Jamestown	4.8	21.6
108N 28W	Judson	6.0	2.5
108N 25W	LeRay	12.9	10.0
109N 26W	Lime	6.2	4.3
107N 29W	Lincoln	16.3	0.1
106N 27W	Lyra	2.3	0.0
108N 26W	Mankato	5.7	2.2
105N 26W	Mapleton	7.6	0.9
107N 25W	McPherson	4.8	2.3
106N 25W	Medo	4.6	1.6
109N 28W	Nicollet	0.0	0.0
105N 29W	Pleasant Mound	2.4	0.0
107N 27W	Rapidan	0.5	0.0
105N 28W	Shelby	1.4	2.9
108N 27W	South Bend	1.5	1.7
105N 27W	Sterling	4.2	9.0
106N 28W	Vernon Center	2.8	0.0
Blue Earth County Total		5.1	3.3

Table 2.--Cummulative Drainage by Decade for Blue Earth County.

Congressional Township	Civil Township	1890 1899	1900 1909	1910 1919	1920 1929	1930 1939	1940 1949	1950 1959	1960 1969	1970 1978
106N 26W	Beauford	0.0	0.0	3.4	22.9	22.9	22.9	31.8	32.4	32.4
109N 27W	Belgrade			No Ditch Drainage in Belgrade Township						
108N 29W	Butternut Valley	0.0	0.0	27.1	44.6	44.6	44.6	86.9	86.9	86.9
109N 29W	Cambria	0.0	0.0	17.4	24.0	24.0	24.0	25.2	25.9	25.9
106N 29W	Ceresco	0.0	0.0	2.7	13.4	13.4	13.4	13.4	14.8	14.8
105N 25W	Danville	0.0	26.8	27.9	27.9	27.9	27.9	27.9	28.8	28.8
107N 26W	Decoria	0.0	2.9	7.5	12.4	12.4	12.4	21.3	30.6	45.0
107N 28W	Garden City	0.0	0.0	6.2	29.8	29.8	29.8	29.8	30.8	30.8
109N 25W	Jamestown	0.0	23.4	23.4	23.4	23.4	23.4	23.4	23.4	26.4
108N 28W	Judson	0.0	0.0	33.6	38.2	38.2	40.3	44.3	44.5	44.5
108N 25W	LeRay	0.0	23.6	45.0	45.0	45.0	45.0	46.4	46.4	47.9
109N 26W	Lime	0.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
107N 29W	Lincoln	0.0	0.0	72.1	89.0	89.0	89.0	91.3	91.3	91.3
106N 27W	Lyra	0.0	11.9	36.3	46.0	46.0	46.0	46.0	46.0	46.0
108N 26W	Mankato	0.0	6.8	14.5	16.7	16.7	16.7	16.7	16.7	16.7
105N 26W	Mapleton	0.0	12.0	30.3	44.8	44.8	44.8	44.8	45.7	48.6
107N 25W	McPherson	7.7	10.2	20.0	22.2	24.4	38.9	49.2	64.2	64.2
106N 25W	Medo	3.4	21.5	22.2	22.2	22.2	22.2	22.2	22.2	29.8
109N 28W	Nicollet			No Ditch Drainage in Nicollet Township						
105N 29W	Pleasant Mound	0.0	0.0	7.8	21.5	21.5	27.2	31.7	34.3	34.3
107N 27W	Rapidan	0.0	0.0	0.0	3.1	3.1	3.1	3.1	3.1	3.1
105N 28W	Shelby	0.0	0.0	21.2	38.8	38.8	38.8	43.9	45.4	48.5
108N 27W	South Bend	0.0	0.0	0.0	3.7	3.7	3.7	3.7	3.7	3.7
105N 27W	Sterling	0.0	0.0	11.7	25.2	25.2	25.2	36.0	38.6	46.1
106N 28W	Vernon Center	0.0	0.0	7.9	13.9	13.9	13.9	54.6	54.6	54.6
Blue Earth County %		.5	6.4	20.1	28.8	28.9	29.9	36.5	38.3	39.9
Blue Earth County Total Miles Ditch Drainage		4.02	49.23	154.16	220.97	221.79	229.86	280.47	293.75	307.39

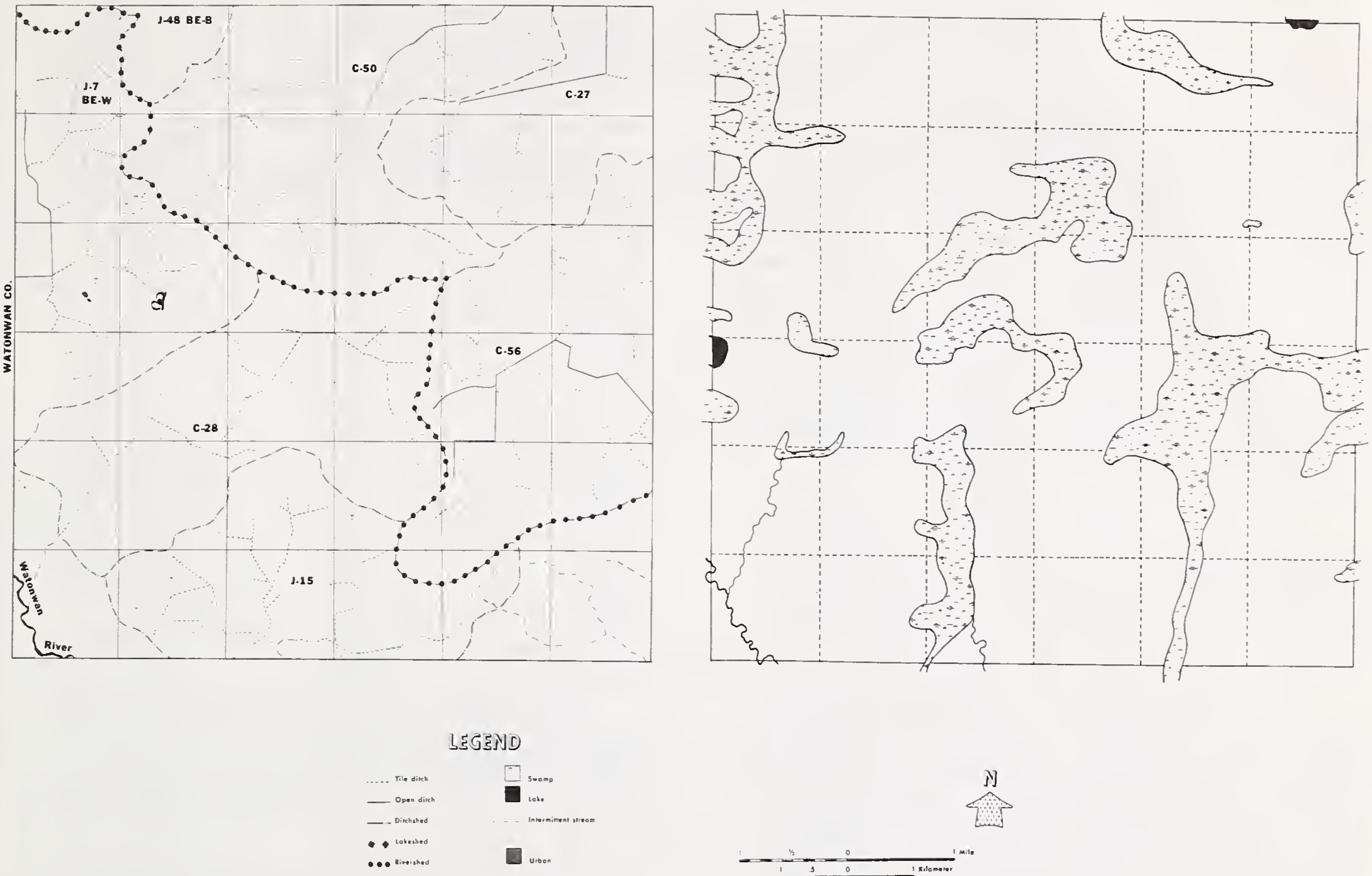

Figure 3.--Present Surface Hydrology and 1854 General Land Survey for Lincoln Township, Blue Earth County.

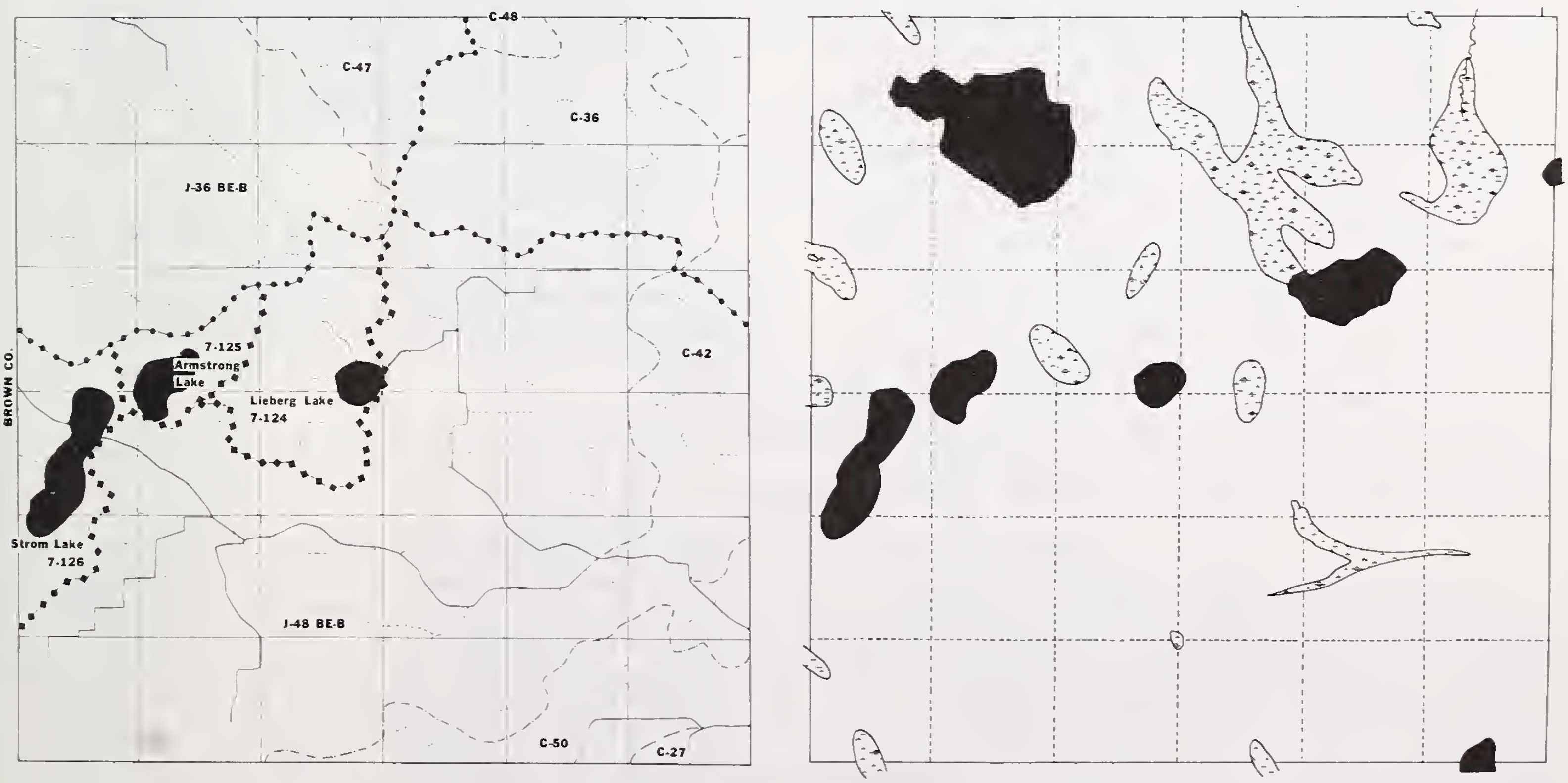

Figure 4.--Present Surface Hydrology and 1854 General Land Survey for Butternut Valley Township, Blue Earth County.

Constitutionality of Drainage

"By virtue of its police power, the power of eminent domain, or the general taxing power, the state (Minnesota) may provide for the construction of drains for draining marshy and overflowed districts" (C.J.S. p. 232, 1941). Police power is "the power vested in the state legislature to establish laws, ordinances, and statutes not repugnant to the constitution and for the good and welfare of the subjects of the state or common wealth." (Blacks law Dictionary, Revised 4th edition, 1968). "Eminent domain" is the right of the state, through its regular organization, to reassert, either temporarily or permanently, its dominion over any portion of the soil of the state on account of public exigency and for the public good."

One aspect these three powers have in common is that they can only be exercised in situations where the public will benefit. Therefore, for drainage to be constitutional it must be shown to benefit the public.

Although drainage has always been done ostensibly to benefit the public through the improvement of health, highways or to prevent flooding, the defacto reason for most drainage has been improve agriculture productivity. With this being true, the constitutionality of drainage for agricultural purposes was soon contested. In 1900 a Minnesota supreme court case was tried to determine the constitutionality of chapter 91 of the 1877 laws that permitted the taking of land for husbandry. (In re Henge-Hendrum Ditch No. 1, 1900, 82 N.W. 1094). The court found: "It does not matter than in accomplishing the public objects of the act private interests are (incidentally) advanced." The court also maintained in this case that the fact that large tracts of otherwise wastelands may be thus reclaimed and made suitable for agricultural purposes is deemed and held to constitute a public benefit." Futhermore, the court reaffirmed the constitutionality of agricultural drainage in saying: "Where the laws have for their object the reclamation of large tracts of wet and swampy lands for agricultural purposes, they are sustained under the right of eminent domain."

The matter of public health has been an important factor in the drainage proceedings of Minnesota. Although the statues implied that agricultural drainage, was a secondary or incidental reason for drainage, this was definitely not the case. In Sellen v. McLeod County (1925) 205 N.W. 625 succintly stated the true reasons for most drainage. Sellen v. McLeod N.W. 625 (1925) "The matter of public health has been an unimportant factor of drainage proceedings in this state. While the statute requires that a proposed ditch will promote the public health, public health has not been the primary object of most drainage proceedings in this state, but rather the reclamation of waste lands. Although it was doubted at one time, it is now fairly well settled that the reclamation of such lands for agricultural purposes, although inuring directly to the benefit of the (private) landowners, thereof, it is also a benefit to the prosperity of the community as a whole by enlaring the productive area of the state."

Although the drainage code still retains the proposition that drainage for agricultural purposes is a benefit to the public, this belief is presently in transition. The legislature and the judiciary have now come to realize that the general public benefit of any lake, swamp, or wetland drainage, should be thoroughly weighed against the possible environmental disruptions caused therefrom.

The extent of the transition can be seen in a decision, dated May 7, 1972, by the Fifth Judicial District Court, when they denied a petition to construct Nicollet County Ditch No. 93. The Court stated that:

"Consideration of all relevant factors, as required by statute, led this court to conclude that the ditch should not proceed. If the situation changes so that diversion of farmlands out of production is no longer sought in the public interest, the matter should be reconsidered in light of all relevant factors." (Petition, 1972) The diversion of farmlands in this case referred to "set-aside" programs.

Bonnema (1972) stated that "This decision prevented the drainage of 200 acres of type III and IV wetlands, and sets a precedent in preventing drainage of valuable wildlife marshes".

Blue Earth County Ditch Petition Survey

An historic tabulation of reasons for drainage used in the petitions for Blue Earth County is shown in Table 3. Although these petitions involve much of legal jargon and are influenced by the constitutional definitions that support drainage at the time the petitions were presented, it does appear that a trend is present. There appears to be a shift from offensive (making land useable) to defensive (protecting land and highways) with time.

Table 3.--Reasons for drainage in Blue Earth County derived from drainage petitions.

Decade	# of Petitions		Hydrologic			Agricultural						Highway		Public Benefit			# "O"	# "D"
			4	6	13	1	7	8	10	12	14	5	9	2	3	11		
1890-99	2	#	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
		%	0	0	0	0	0	0	0	0	0	0	0	50	0	50		
1900-99	11		4	5	0	0	1	0	0	1	0	0	1	11	11	11	8	0
			36	45	0	0	9	0	0	9	0	0	9	100	100	100		
1910-19	71		28	68	0	1	22	0	0	40	7	7	14	71	70	70	144	8
			39	96	0	1	31	0	0	56	10	10	20	100	99	99		
1920-29	19		3	18	0	0	3	0	1	8	2	5	2	19	19	19	31	5
			16	95	0	0	16	0	5	42	11	26	11	100	100	100		
1930-39	0																0	0
1940-49	4		0	0	0	2	2	2	2	0	0	1	0	3	3	0	4	3
			0	0	0	50	50	50	50	0	0	25	0	75	75	0		
1950-59	8		1	3	0	4	1	1	2	2	0	5	0	7	7	1	7	9
			13	38	0	50	13	13	25	25	0	63	0	88	88	13		
1960-69	10		0	2	7	1	1	0	2	1	0	8	0	10	10	0	4	16
			0	20	70	10	10	0	20	10	0	80	0	100	100	0		
1970-	7		0	0	3	3	0	0	0	0	0	5	0	7	7	0	0	11
			0	0	43	43	0	0	0	0	0	71	0	100	100	0		
Totals	132		36	96	10	11	30	3	7	52	9	31	17	129	127	102		

1. Prevent flooding of agriculture land
2. Promote or improve public health
3. Be of public utility
4. Enhance the value of land
5. Prevent flooding of roads
6. Reclamation of wet and overflowed lands
7. Make land useable for cultivation
8. Make land useable for pasture
9. Improvement of highways (drain land for construction)
10. Increase productivity of land
11. Public welfare and convenience
12. Make land available for agricultural uses
13. Prevent flooding of land
14. Make land valuable for agricultural uses

Offensive	Defensive
6, 7, 8, 9, 12	1, 5, 13

DRAINAGE DITCH-RIVER
WATER QUALITY CASE STUDY

We are presently completing a four year study of County Ditch 59 in Le Sueur County. The study involves an attempt to determine whether the drainage ditch or the river it runs into is the primary source of nutrient loading of Lake Tetonka (fig. 5).

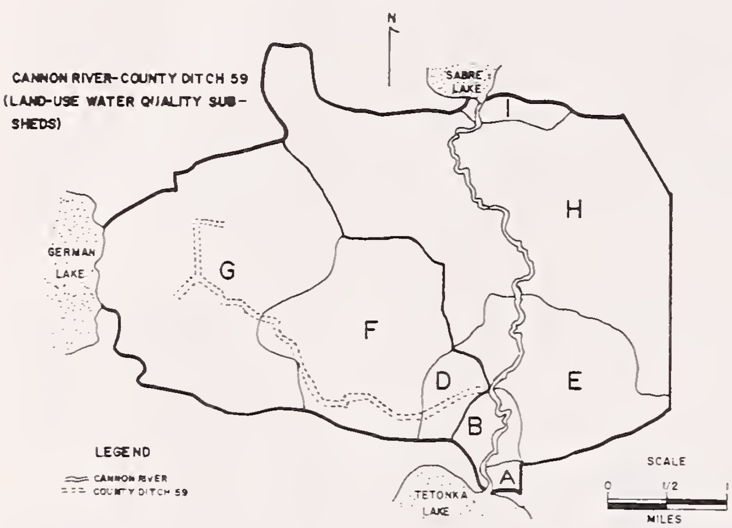

Figure 5.--Study area for ditch shed versus river shed water quality case study.

Land-use, soils, fertilizer application, feedlots, and dwellings were quantified for each subshed in order to account for differences in water quality. The land use data was obtained by aerial photographs, ground truth surveys, and questionnaires. The land-use for 1976 is shown in Table 4. If one compares the Ditch Shed to River Shed it is seen that there is little difference. The same similarity between ditch shed and river shed exist for the other parameters quantified. If one, however, looks at land-use parameters actually bordering the drainage ditch verses the river a different picture emerges. Sixty-six percent of the riparian usage in the ditchshed is for corn whereas only ten percent of the riparian usage is in corn along the river. Sixty-seven percent of the riparian usage of the river is pasture and only eleven percent is pasture along the ditch. Seventy-eight percent of the riparian area along the ditch is plowed in comparison to only eleven percent on the river. The riparian land use appears to be the main difference between the two sheds. A second difference is that Ditch 59 is bermed along almost its entire length which prevents access by overland flow. Although the river and ditch both have tile inputs, the river also receives overland flow.

Water quality was sampled at the downstream locations within each subshed. Samples were taken at week to two week intervals from 07/02/75 to 08/22/76. Total loads are given in Table 5. If one compares the data at Site D and Site E it is clear that the major loading to Lake Tetonka is coming from the Cannon River upsteam of the confluence of the drainage ditch. If one subtracts the concentration at Site I from Site E for each date and redetermines loads the river appears lower in nutrients.

What is clear from the water quality study is that the water leaving this particular drainage ditch is low in nutrients and not the major cause of loading of Lake Tetonka.

Early observation of drainage ditches in our area often revealed a large standing crop of submerged aquatic macrophytes and we subsequently investigated the amount of macrophyte nutrient inactivation within County Drainage Ditch 59. Table 6 shows the nutrient tie up by macrophyte for the ditch. The total phosphorus tie up was 11.1 Kg compared to the study period from the flow of 188 Kg or about six percent. The actual harvesting of these plants would represent a removal of less than one percent of what was entering Lake Tetonka. Further, the top four centimeters of sediment in the ditch contained 5.6 times as much phosphorus as the macrophytes.

Table 6.--Total nutrient content of the top four centimeters of sediment compared to the macrophytic nutrient inactivation in County Ditch No. 59. (Hill 1978)

Total Kjeldahl Nitrogen	
Sediment	864.0 Kg
Macrophyte	62.1 Kg
Sediment/macrophyte	13.4
Total Phosphorus	
Sediment	62.1 Kg
Macrophyte	11.1 Kg
Sediment/macrophyte	5.6
Organic Carbon	
Sediment	7720.0 Kg
Macrophyte	956.0 Kg
Sediment/macrophyte	8.1

It appears that the natural river system is either unable to inactivate the nutrients coming in from Lake Sabre or does so but receives further loading from its watershed, presumably by overland flow. The ditch on

Table 4.--Land use of study area by sub shed for 1976.

Sheds (acres)	Corn	Forest	Pasture	Soybeans	Hay	Small grains	Water	Swamp	Alfalfa	Sunflowers	Total	Planimetered area
G	2,622.7	270.3	256.9	357.1	7.7	15.4	76.8	149.8	76.8	-	3,833.5	3,840.8
F	1,519.3	240.7	79.4	420.8	-	23.8	33.3	-	95.1	-	2,376.4	2,377.6
D	195.8	22.1	48.9	24.6	-	47.8	-	-	6.8	-	346.0	341.8
Ditch Shed	4,337.8	497.1	385.2	802.5	7.7	87.0	110.1	149.8	178.7	-	6,555.9	6,559.4
I	132.3	57.0	11.4	-	-	-	-	-	6.0	-	206.7	206.7
H	2,951.8	423.2	859.1	877.3	5.5	16.5	-	16.5	248.3	110.3	5,508.5	5,517.4
E	1,438.1	121.7	138.0	104.9	18.7	22.5	-	-	28.1	-	1,872.0	1,872.6
River Shed	4,522.2	601.9	1,008.5	982.2	24.2	39.2	-	16.5	282.4	110.3	7,587.4	7,596.7
C (total GFDIHE)	8,860.0	1,099.0	1,393.7	1,784.7	31.9	126.2	110.1	166.3	461.1	110.3	14,143.3	14,156.1
B	149.9	25.9	85.8	10.3	-	83.1	-	-	-	-	355.0	355.2
A	69.5	9.1	-	3.4	-	12.7	-	-	-	-	94.7	94.7
GRAND TOTAL	9,079.4	1,134.0	1,479.5	1,798.4	31.9	222.0	110.1	166.3	461.1	110.3	14,815.0	14,606.0
Shed (percent)												
G	68.3	7.0	6.7	9.3	0.2	0.4	2.0	3.9	2.0	-	99.8	100.0
F	63.9	8.6	3.3	17.7	-	1.0	1.4	-	4.0	-	99.9	100.0
D	57.3	6.5	14.3	7.2	-	14.0	-	-	2.0	-	101.2	100.0
Ditch Shed	66.2	7.6	5.9	12.2	0.1	1.3	1.7	2.3	2.7	-	99.9	100.0
I	64.0	27.6	5.5	-	-	-	-	-	2.9	-	100.0	100.0
H	53.5	7.7	15.6	15.9	0.1	0.3	-	0.3	4.5	2.0	99.8	100.0
E	76.8	6.5	7.4	5.6	1.0	1.2	-	-	1.5	-	100.0	100.0
River Shed	59.6	7.9	13.3	12.9	0.3	0.5	-	0.2	3.7	1.5	99.9	100.0
C (total GFDIHE)	62.6	7.8	9.8	12.6	0.2	0.9	0.8	1.2	3.3	0.8	99.9	100.0
B	42.2	7.3	24.2	2.9	-	23.4	-	-	-	-	99.9	100.0
A	73.4	9.6	-	3.6	-	13.4	-	-	-	-	100.0	100.0
GRAND TOTAL	61.3	7.6	10.0	12.1	0.2	1.5	0.7	1.1	3.1	0.7	101.4	100.0

Table 5.--Total cummulative nutrient loading by sub shed for 14 month study period in Kg.

	PO_4	Total PO_4	NO_3	Total Dissolved Solid	Total Flow*
B	2,339.47	3,808.77	15,547.73	2,563,695.50	5,392.679.20
C	4,711.84	8,080.50	28,258.20	5,391,524.70	11,247,036.40
E	6,208.25	9,459.90	30,619.25	3,679.988.50	11,831,215.10
H	2,856.21	4,869.24	15,577.40	2,307,897.60	6,630,660.00
I	4,113.38	6,654.04	13,717.90	3,028.999.30	8,509,104.20
D	110.41	187.94	2,045.58	345.902.66	838,643.40
F	89.81	138.79	1,858.07	351.889.30	838,281.22
G	28.99	63.30	595.13	76,688.46	227,403.78
E-I**	43.25	151.90	1,185.74	4,096.66	3,262,115.26

* in m^3
** by recalculation

the other hand is able to inactivate both biologically through aquatic plants and biologically and/or physically through sedimentation. Further, the ditch is not influenced by overland flow.

CONCLUSION

Important decisions regarding wetlands, public waters, water resource planning and agricultural practices are being made now on either poor data or a lack of data. There is no question about the fact that drainage is a major factor on the economy, wildlife, agriculture, and hydrology of Minnesota.

It is not a question of saying all drainage is bad or must cease. The case study discussed shows that in fact the drainage ditch water has a dilution and thus beneficial effect on the receiving lake. There are, however, many types of ditches and we are presently investigating the water chemistry resulting from a variety of ditches. Variables include construction (bermed or not bermed), adjacent land-use, depth of ditches in relation to water level and the nature of the riparian plant community.

It is my opinion that the construction and maintenance of drainage ditches should follow the guidelines of a broad based environmental assessment and that it is possible to have both quality agriculture and water resources within Minnesota.

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